evolution

A Centre of Excellence for Civil Service Examination Guidance

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Ecology (Botany Optional)

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Prescribed syllabus of Ecology

For Civil Service Examination (Main) of Botany optional

Concept of ecosystem; Ecological factors; Concepts and dynamics of community; Plant succession; Concept of biosphere; Ecosystems; Conservation; Pollution and its control (including phytoremediation); Plant indicators; Environment (Protection) Act.

Forest types of India - Ecological and economic importance of forests, afforestation, deforestation and social forestry; Endangered plants, endemism, IUCN categories, Red Data Books; Biodiversity and its conservation; Protected Area Network; Convention on Biological Diversity; Farmers' Rights and Intellectual Property Rights; Concept of Sustainable Development; Biogeochemical cycles; Global warming and climatic change; Invasive species; Environmental Impact Assessment; Phytogeographical regions of India

Chapter 1: Concept of biosphere

Concept of the Biosphere

The part of the earth which supports life and sustains various life activities is known as biosphere. It is the sum of all ecosystems. It integrates all living beings, their relationships and their interaction. In other words, the biosphere is a thin outer shell of earth comprising of atmosphere, oceans and earth crust, within which life occurs.

The biosphere is considered to have evolved, through a process of biogenesis, at least 3.5 billion years ago. The term "biosphere" was coined by geologist Eduard Suess in 1875.

According to GE Hutchinson three things make the earth special to support the biosphere and life.

1. It is a region in which liquid water can exist in substantial quantities.
2. It receives an ample supply of energy from an external source, the Sun; and
3. Within it, there are interfaces between the liquid, the solid and the gaseous phases of matter.

Extent of the Biosphere

The thickness of the biosphere on earth cannot be measured because the living organisms can occupy extremely diverse locations on the earth. For example:

- Birds typically fly at altitudes of 650 to 2000 meters and fishes can be found down to 8,372 meters in the Puerto-Rican Trench.
- Ruppell's Vulture has been found at altitudes of 11,300 meters; Bar-headed Geese migrate at altitudes of at least 8,300 meters (over Mount Everest).
- Yaks live at elevations between 3,200 to 5,400 meters above sea level; mountain goats live up to 3,050 meters. Tine palm or mountain coconut found 3,400 meters above sea level.
- Microscopic organisms (e.g., bacteria and archaea) live at extremes; their habitat extends from 5,400 meters above sea level to at least 9,000 meters below sea level.

Components of the Biosphere

The biosphere is a global ecosystem composed of 2 principal components:

1. **Living organisms (biota)**: The biotic portion includes three general categories of organisms based on their methods of acquiring energy: the primary producers (green plants); the consumers, (all the animals); and the decomposers, (the microorganisms).
2. **Abiotic (nonliving) factors**: The abiotic portion in the biosphere includes the flow of energy, nutrients, water, and gases and the concentrations of organic and inorganic substances in the environment. From these factors the biota derives energy and nutrients.

Living Organisms (biota)

In biosphere, 3 to 30 million species of plants, animals, fungi, prokaryotes, and acellular eukaryotes may be present. Of this total, only about 1.4 million species have been named so far,

and less than 1 percent have been studied for their ecological relationships and their role in ecosystems.

This tremendous diversity of life is organized into natural ecological groups. As life has evolved, populations of organisms separated into different species and became reproductively isolated from one another. These species are organized into complex biological communities. The interactions in these communities with physical environments formed ecosystems through which the energy and nutrients necessary for life flow and cycle. The species and their physical environments vary across the globe, creating various biomes. The sum total of these biomes is the biosphere.

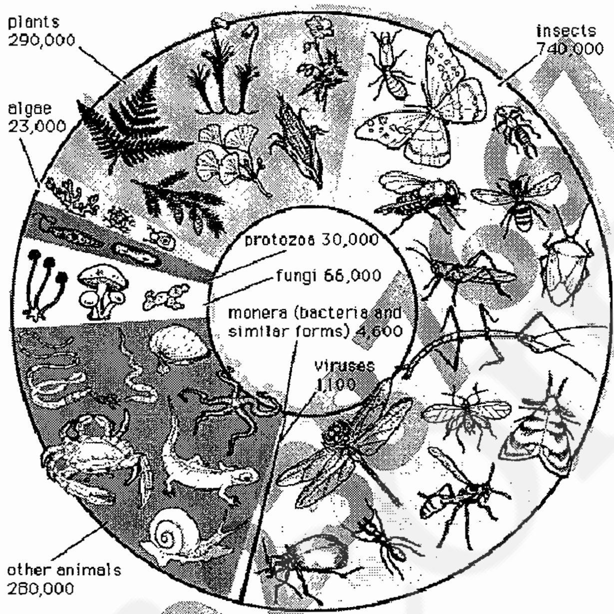


Figure 1: The diversity of the Biota in the Biosphere

Abiotic (nonliving) factors

The non-living factors are either resources or conditions. Conditions are variable environmental factors; it is not consumed by an organism and is hence not depletable. But it has direct physiological and behavioral impacts on the organisms, such as temperature, acidity, salinity, osmolarity and radiation.

Environmental conditions are constantly changing. The Earth's diurnal rotation and annual rotation around the sun bring changes in temperature and radiation. The centrifugal motion of the planet and convection currents along with the changes in temperature and radiation cause climatic changes. Conditions may also be altered by the impact of other organisms. For example, in the absence of oxygen, heterotrophic bacteria will reduce the pH of soil (i.e. increase its acidity).

A resource is anything, which an organism depletes. This includes organic food, inorganic nutrients (for plants), light and space. The single most important resource is solar radiation, which is the sole source of energy for green plants.

It is important to consider that the dichotomy between conditions and resources only exists for a particular organism. Thus, solar radiation is a condition for an insect, but a resource for a plant. Further, occasionally the same factor can be both a resource and a condition. For example, a plant uses water as a resource, but heavy rainfall, which might lodge the plant or wash it away, represents a condition.

Working of the Biosphere

The elements—hydrogen, oxygen, carbon, nitrogen, phosphorus, and sulphur—form the core protoplasm of organisms, and the first four of these elements make up about 99 percent of the mass of most cells. These elements are cycled in the biosphere through the biogeochemical cycles. This ensures constant energy and material flow within the biosphere.

Chapter 2. Biomes

Introduction

Scientists have developed the term Biome to describe areas on the earth with similar climate, plants, and animals.

Biomes are defined as "the world's major communities, classified according to the predominant vegetation and characterized by adaptations of organisms to that particular environment" (Campbell 1996).

Alternatively, Krebs (1985) defined biomes in the following words:

A biome is a major regional group of distinctive plant and animal communities best adapted to the region's physical natural environment, latitude, elevation, and terrain. A biome is made up of ecoregions or communities at stable steady state and all associated transitional, disturbed, or degraded, vegetation, fauna and soils, but can often be identified by the climax vegetation type.

Types of Biomes

The biomes of the world have been classified by various workers and conservation agencies. Previously the most widely used classification was the Whittaker's Classification of Biomes. However, since 2004 – most of the ecologists follow the WWF Classification of Biomes across the world. This classification is an expanded version of the Whittaker's Classification of Biomes.

The WWF Classification of Biomes

A team of biologists convened by the World Wildlife Fund (WWF) developed an ecological land classification system that identified 14 terrestrial biomes and 12 aquatic biomes (in total 26 Biomes). They have further divided the world's land area into 867 terrestrial ecoregions.

This classification is used to define the Global 200 list of ecoregions identified by the (WWF) as priorities for conservation. The WWF identified biomes are as follows:

Terrestrial Biomes

1. Tundra (arctic)
2. Boreal forests/taiga (subarctic, humid)
3. Temperate coniferous forests (temperate, humid to semi-humid)
4. Temperate broadleaf and mixed forests (temperate, humid)
5. Temperate grasslands, savannas, and shrublands (temperate, semi-arid)
6. Mediterranean forests, woodlands, and shrub (temperate warm, semi-humid to semi-arid with winter rainfall)
7. Tropical and subtropical coniferous forests (tropical and subtropical, semi-humid)
8. Tropical and subtropical moist broadleaf forests (tropical and subtropical, humid)
9. Tropical and subtropical dry broadleaf forests (tropical and subtropical, semi-humid)
10. Tropical and subtropical grasslands, savannas, and shrublands (tropical and subtropical, semi-arid)
11. Montane grasslands and shrublands (alpine or montane climate)
12. Deserts and xeric shrublands (temperate to tropical, arid)
13. Mangrove (subtropical and tropical, salt water inundated)
14. Flooded grasslands and savannas (temperate to tropical, fresh or brackish water inundated)

Aquatic Biomes

1. Continental Shelf
2. Littoral/Intertidal Zone
3. Riparian
4. Pond
5. Coral Reef
6. Kelp Forest
7. Pack Ice
8. Hydrothermal Vents
9. Cold Seeps
10. Benthic Zone
11. Pelagic Zone
12. Neritic Zone

The factors affecting distribution of biomes

The factors affecting distribution of biomes include:

1. Temperature and sunlight (angle of the sun and how the sun's rays hit the earth affect heating of the planet)
2. Water and precipitation - ranges from dry to wet areas
3. Wind patterns - affects temperature and water loss
4. Rocks and soil (pH, mineral content, salinity, etc.)

A short description of important types of biomes

The important types of biomes are briefly described in the table below.

Biomes	Physical Characteristics	Plants	Animals
1. Tundra	2 seasons, dry, frozen deserts, winter: Extreme cold and snow, summer: flooding caused By snow melt, permafrost layer (permanently Frozen, about 3 m below ground), location: far North and far south - towards the polar ice caps, Average temperature: 10 degrees celsius Rainfall: 25 cm/yr Snow: 10 - 20 cm/yr	No trees, dominated by mosses and Lichens and grasses, some small Shrubs	Insect blooms, large hooved mammals (caribou, musk ox), bears, Wolves, small rodents (lemmings), Migrants during the breeding Season
2. Taiga/Boreal Forest	Long winter, short fall and spring, 2-3 months of summer, wetter seasons, Heavy rain and snow Location: coniferous forest, far nothern and far Southern latitudes	Trees 5 - 10 m high, Boreal forest, conifers - pine, spruce, bog plants (ferns and mosses)	Diverse array of migrants from the tropics with few resident species (moose, bear, lynx, fox, voles), large insect blooms

3. Temperate Deciduous Forest	4 seasons, rainfall: 80-140 cm/yr	Complex levels of vegetation deciduous trees, loose leaves in fall	Diverse array of migrants from the tropics and resident species
4. Savanna	Dry, rainfall: 90 - 150 cm/yr Location: tropical to subtropical, 3 seasons	Grasses, forbs, trees short and (2m tall) Clumped together (10 m tall)	Large ungulates, large predators
5. Temperate Grassland	Temperate and some subartic grassland (extreme northern prairies - steppes and Some extreme southern grasslands - Pampas of argentina) Rainfall: 25-70 cm/yr	Grasses	Large ungulates
6. Chaparral	Mild wet winter followed by hot, dry, summer Many plants dependent on regular fires Associated with chaparral Location: near coastlines (california, chile, Mediterranean	Short trees and shrubs	Diversity of mammals, birds, Insects, etc. That like dry Habitats
7. Desert	Very dry, rainfall: less than 25 cm/yr Location: primarily equatorial but some reach Into temperate regions	Cactus, sagebrush, creosote And shrubs	Small rodents, reptiles
8. Tropical rainforest	Very wet - heavy rainfall, soil - poor in nutrients, Temperature constant throughouth the year Wet and dry seasons Location: equatorial, 23.5 degree n latitude - 23.5 degree s latitude	Large trees-broad-leaved evergreens, Epiphytes, not much forest Floor vegetation (little sunlight). Canopy 30 - 40 m above ground	Highest diversity of animals
Aquatic Biome	Freshwater and marine		
1. Marine - Pelagic Zone	Deep ocean, dependent on upwellings	Algae	Various birds, large mammals, fish
2. Marine - Benthic	Ocean floor, no light	None	Detritus feeders, predatory fish
3. Marine - Estuaries	Where rivers flow into the ocean, mix of saltwater and freshwater, marshes rich in plants and animals	Aquatic vegetation, marsh plants	Rich variety
4. Marine - Intertidal zone	Shoreline to shallow waters	Algae	Marine worms, clams, oysters, crustaceans
5. Coral reefs	Tropical oceans	Algae	Coral, fish

Significance of studying biomes

The study of biomes is of immense significance. Biomes have changed and moved many times during the history of life on Earth. More recently, human activities have drastically altered these communities. Thus, conservation and preservation of biomes should be a major concern to all.

Chapter 3: Ecosystems

The concept

An ecosystem is a naturally occurring assemblage of organisms (plant, animal and other living organisms—also referred to as a biotic community or biocoenosis) living together with their environment (or biotope), functioning as a loose unit. Ecosystem, a relatively self-contained, dynamic system composed of a natural community along with its physical environment. It is the complex of living organisms, their physical environment, and all their interrelationships in a particular unit of space.

The definition by E.P. Odum: An ecosystem is any ecological unit that includes **all of the organisms** (i.e. the community) in a given area, interacting with the **physical environment** so that a flow of energy leads to:

- a clearly defined trophic structure
- biotic diversity, and
- materials cycles
  i.e., exchange of materials between
  - biotic (i.e. living parts within the system), and
  - abiotic (i.e. non-living parts within the system, and
  - exchanges with the environment external to the ecosystem.

History of the concept: *The* term ecosystem first appeared in a 1935 publication by the British ecologist **Arthur Tansley**. However, the term had been coined already in 1930 by Tansley's colleague Roy Clapham. Tansley expanded on the term in his later work, adding the ecotope concept to define the spatial context of ecosystems. Modern usage of the term derives from the work of **Raymond Lindeman** in his classic study of a Minnesota lake.

The attributes of an ecosystem

Modern ecologists identify **6 distinct attributes** of an ecosystem.

1. **Structure**:
   - ABIOTIC COMPONENTS
     a. Atmosphere
     b. Hydrosphere
     c. Lithosphere
     d. plus sun energy
   - BIOTIC COMPONENTS
     a. Producer (plant) communities - autotrophic
     b. Consumer (animal) communities - heterotrophic

c. Decomposer (microbial) communities - heterotrophic

2. **Function**: exchanges of matter and energy between abiotic and biotic components
3. **Complexity**: results from a high level of biological integration
4. **Interaction** and **interdependency**
5. **Spatial dimension**: no inherent definition
6. **Temporal change**: there are successional stages in the biotic communities

The structure of an ecosystem

An **ecosystem** can be categorized into its abiotic constituents, including minerals, climate, soil, water, sunlight, and all other nonliving elements, and its biotic constituents, consisting of all its living members. Linking these constituents together are two major forces: the flow of energy through the **ecosystem**, and the cycling of nutrients within the **ecosystem**.

Biotic components

The biotic components in an ecosystem are associated with each other in numerous ways, but for ecological analysis the most useful **categorization is based on the organism's role in the flow of material and energy within the ecosystem.**

Accordingly, there are **three classes of biotic components** within an ecosystem.

1. **Autotrophs:** An autotroph (from the Greek *autos* = self and *trophe* = nutrition) is an organism that produces organic compounds from carbon dioxide as a carbon source, using either light or reactions of inorganic chemical compounds as a source of energy. Plants, algae, cyanobacteria and some eubacteria using photosynthesis are **photolithoautotrophs**; bacteria that utilize the oxidation of inorganic compounds such as hydrogen sulfide or ferrous iron as an energy source are **chemolithoautotrophs**. *Autotrophs* are a vital part of a food chain. They take energy from the sun or from inorganic sources and convert it into a form (organic molecules) that they use to carry out biological functions including cell growth, and that other organisms (called **heterotrophs**) utilize as food.

2. **Heterotrophs:** A **heterotroph** (Greek *heteron* = (an)other and *trophe* = nutrition) is an organism that requires organic substrates to get its carbon for growth and development. Contrast with autotrophs which use carbon dioxide as sole carbon source. All animals are heterotrophic, as well as fungi and many bacteria. Some parasitic plants have also turned fully or partially heterotrophic, whereas carnivorous plants use their flesh diet to augment their nitrogen supply, but are still autotrophic. Heterotrophs are unable to synthesize organic, carbon based compounds independently from the inorganic environment's sources. For a species to be termed a heterotroph, it must obtain its carbon from organic compounds.

3. **Decomposers:** Decomposers are organisms (often fungi or bacteria) that break down organic materials to gain nutrients and energy. Decomposition is a natural process that will happen by default, but decomposers accelerate the process. The role that decomposers perform in an ecosystem is extremely important. When an organism dies, it leaves behind nutrients that are locked tightly together. A scavenger may eat the carcass, but its feces still contains a considerable amount of unused energy and nutrients. Decomposers such as fungi will later induce further breakdown. This last step releases raw nutrients (such as nitrogen, phosphorus, and magnesium) in a form usable to plants, which quickly incorporate the

chemicals into their own cells. This process greatly increases the nutrient-load of an ecosystem, in turn allowing for greater biodiversity. Decomposers also convert organic carbon into Carbon-di-oxide, which can later be trapped by photosynthesizers.

Abiotic components

Abiotic components are nonliving chemical and physical factors in the environment. Often, these are described as light, temperature, water, atmospheric gases, wind as well as soil (edaphic) and physiographic (nature of land surface) factors. The non-living factors are either **resources** or **conditions**. These relations vary from one organism to another.

Important Abiotic Components are 7 in number:

1. Light
2. Temperature
3. Water
4. Atmospheric gases
5. Wind
6. Soil (edaphic)
7. Physiographic (nature of land surface) factors.

A short note on Abiotic Ecological Factors

1. Light

Light energy (sunlight) is the primary source of energy in nearly all ecosystems. It is the energy that is used by green plants (which contain chlorophyll) during the process of photosynthesis; a process during which plants manufacture organic substances by combining inorganic substances. Visible light is of the greatest importance to plants because it is necessary for photosynthesis. Factors such as ***quality of light, intensity of light*** and the ***length of the light period (day length)*** play an important part in an ecosystem.

- **Quality of light (wavelength or colour)**: Plants absorb blue and red light during photosynthesis. In terrestrial ecosystems the quality of light does not change much. In aquatic ecosystems, the quality of light can be a limiting factor. Both blue and red light are absorbed and as a result do not penetrate deeply into the water. To compensate for this, some algae have additional pigments which are able to absorb other colours as well.

- **Light intensity ("strength" of light)**: The intensity of the light that reaches the earth varies according to the latitude and season of the year. The southern hemisphere receives less than 12 hours of sunlight during the period between the 21st March and the 23rd of September, but receives more than 12 hours of sunlight during the following six months.

- **Day length (length of the light period)**: Certain plants flower only during certain times of the year. One of the reasons for this is that these plants are able to "measure" the length of the night (dark periods). However, it was thought that it is the day length (light periods) to which plants reacted and this phenomenon was termed **photoperiodism.** Photoperiodism can be defined as the relative lengths of daylight and darkness that effect the physiology and behaviour of an organism.

1. **Short-day Plants:** These plants flower only if they experience nights which are longer than a certain critical length. The chrysanthemum (*Chrysanthemum sp.*), the poinsettia (*Euphorbia pulcherrima*) and the thorn-apple (*Datura stramonium*) are examples of short day plants.

2. **Long-day plants:** These plants flower if they experience nights which are shorter than a certain critical length. Spinach, wheat, barley, clover and radish are examples of long plants.

3. **Day-neutral plants:** The flowering of day-neutral plants is not influenced by night length. The tomato (*Lycopersicon esculeutum*) and the maize plant (*Zea mays*) are examples of day-neutral plants.

The following definitions are also important:

- **Phototropism**
  Phototropism is the directional growth of plants in response to light where the direction of the stimulus determines the direction of movement; stems demonstrate positive phototropism i.e. they came towards the light when they grow.

- **Phototaxis**
  Phototaxis is the movement of the whole organism in response to a unilateral light source, where the stimulus determines the direction of movement.

- **Photokinesis**
  Variation in intensity of locomotory activity of animals which is dependent on the intensity of light stimulation, and not the direction, is called photokinesis.

- **Photonasty**
  Photonasty is the movement of parts of a plant in response to a light source, but the direction of the stimulus does not determine the direction of the movement of the plant.

Light requirements of plants differ and as a result distinct layers, or stratification, can be observed in an ecosystem. Plants which grow well in bright sunlight are called **heliophytes** (*Greek helios, sun*) and plants which grow well in shady conditions are known as **sciophytes** (*Greek skia, shade*).

2. Temperature

The distribution of plants and animals is greatly influenced by extremes in temperature for instance the warm season. The occurrence or non-occurrence of frost is a particularly important determinant of plant distribution since many plants cannot prevent their tissues from freezing or survive the freezing and thawing processes. The following are examples of temperature effects with ecosystems:

- the opening of the flowers of various plants during the day and night is often due to temperature difference between the day and night;
- the seed of some plants (biennials) normally germinate in the spring or summer; this phenomenon is well observed in carrots and is called vernalization;
- some fruit trees such as the peach require a cold period each year so that it can blossom in the spring;
- deciduous trees lose their leaves in winter and enter into a state of dormancy, where the buds are covered for protection against the cold;
- the seeds of many plants, e.g. peach and plum, must be exposed to a cold period before they germinate; this chilling ensures that seeds don't germinate during autumn, but after winter, when the seedlings have better chances to survive;
- in animals, a distinction is made between ectothermic ("cold-blooded" or poikilothermic) animals and endothermic ("warm-blooded" or homothermic) animals although the difference is not clear cut;
- in desert conditions are a greater temperature variation between day and night and organisms have distinct periods of activity, for e.g. many cacti flower at night and are pollinated by nocturnal insects;

- seasonal changes have also a great influence on animal life in an ecosystem; torpor in winter is common in reptiles and some mammals in South Africa, but a winter sleep occurs in bears of the northern hemisphere; some animals collect fat or other resources during favourable periods (often summer and autumn) and become dormant (this is called hibernation), there are also animals that are dormant during warm and dry conditions and this is known as aestivation; examples of such animals are snails and the African lung-fish;
- seasonal movements occur in some animals; this phenomenon is called seasonal migration, examples of such animals are migratory locusts, butterflies and various marine animals like whales, penguins and marine turtles.

3. Water

Plant and animal habitats vary from entirely aquatic environments to very dry deserts. Water is essential for life and all organisms depend on it to survive in especially desert areas.

Water requirements of plants

Plants can be classified into 3 groups according to their water requirements:

Hydrophytes

Hydrophytes are plants which grow in water e.g. water-lilies and rushes.

Mesophytes

Mesophytes are plants with average water requirements e.g. roses, sweetpeas.

Xerophytes

Xerophytes are plants which grow in dry environments where they often experience a shortage of water e.g. cacti and often succulents.

Water requirements of animals

Terrestrial animals are also exposed to desiccation and just a few interesting adaptations are mentioned here:

- the body covering limits water loss e.g. the chitinous body covering of insects, the scales of reptiles, the feathers of birds and the hair of mammals
- the tissues of animals may be tolerant to water loss e.g. a camel can live without water for long periods because its body tissues have this adaptation;
- there are also known cases where insects are able to absorb water in the form of water vapour directly from the atmosphere for example the dew from the coastal fog is an important source of moisture for insects of the Namib.

4. Atmospheric gases

The most important gases used by plants and animals are oxygen, carbon dioxide and nitrogen.

Oxygen

Oxygen is used by all living organisms during respiration.

Carbon Dioxide

Carbon dioxide is used by green plants during photosynthesis.

Nitrogen

Nitrogen is made available to plants by certain bacteria and through the action of lightning.

5. Wind: Winds or air currents arise on a world-wide scale as a result of a complex interaction between hot air expanding and rising (convection) in the mid latitudes. This has various effects on the rotation of the earth and results in a centrifugal force which tends to lift the air at the equator. This force is known as the *Coriolis force* and tends to deflect winds to their left of the southern hemisphere and to the right in the northern hemisphere. Winds carry water vapour which may condense and fall in the form of rain, snow or hail. Wind plays a role in pollination and seed dispersal of some plants, as well as the dispersal of some animals, such as insects. Wind erosion can remove and redistribute topsoil, especially where vegetation has been reduced. Warm bergwinds results in desiccation which creates a fire hazard. If plants are exposed to strong prevailing winds are they usually smaller than those in less windy conditions.

6. Soil (edaphic factors)

These factors include soil texture, soil air, soil temperature, soil water, soil solution and pH, together with soil organisms and decaying matter.

Soil texture

The size of soil particles varies from microscopic particles called clay to larger particles called sand. Loam soil is a mixture of sand and clay particles. Sandy soils are suitable for growing plants because they are well-aerated, excess water drains away quickly, they warm up quickly during the day and is easy to cultivate. Sandy soils is unsuitable because they do not retain much water and soon dry out and contain few soil nutrients required for plant growth. Clay soils are suitable for plant growth because they hold large quantities of water and are rich in mineral nutrients. They are unsuitable in that they are badly aerated, soon becomes waterlogged and is difficult to cultivate; It also cold during winter. Loam soils possess desirable properties of both sand and clay - it has a high water retaining capacity, good aeration, good nutrient content and is easily cultivated.

Soil air

Soil air is found in those spaces between the soil particles that are not filled with soil water. The amount of air in a soil depends on how firmly the soil is compacted. In well-aerated soil at least 20% of its volume is made up of air.

Soil temperature

Soil temperature is an important ecological factor. It has been found that the temperature of soil below a depth of about 30cm is almost constant during the day but seasonal temperature differences do occur. At low temperature there is little decay by decay-causing micro-organisms.

Soil water

Soil water can be classified into three types, namely hygroscopic, capillary and gravitational water. **Hygroscopic water** occurs as a thin film of water around each soil particle. **Capillary water** is that water held in the small spaces between the soil particles and **gravitational water** is the water which drains downwards through the soil.

Soil solution

Soil solution is the decaying remains of plants and animals, together with animal excretory products and faeces, form humus. This increases the fertility of the soil.

pH

Acidity or alkalinity of soil (the pH of the soil) influences the biological activity in soil and the availability of certain minerals. Thus the pH of soil has a greater influence on the growth and development of plants. Some plants e.g.azaleas, ericas, ferns and many protea species grow best in acid soils (soils with a pH below 7), while lucerne and many xerophytes grow better in alkaline soils (soils with a pH above 7).

7. Physiographic factors: These factors are those associated with the physical nature of the area, such as altitude, slope of land and the position of the area in relation to the sun or rain-bearing winds. **Altitude** plays a role in vegetations zones. **Slopes** are important when considering the temperature.

Function of Ecosystems

It means exchanges of matter and energy between abiotic and biotic components.

An ecosystem can be categorized into its abiotic constituents, including minerals, climate, soil, water, sunlight, and all other nonliving elements, and its biotic constituents, consisting of all its living members. Linking these constituents together are two major forces: the flow of energy through the ecosystem, and the cycling of nutrients within the ecosystem.

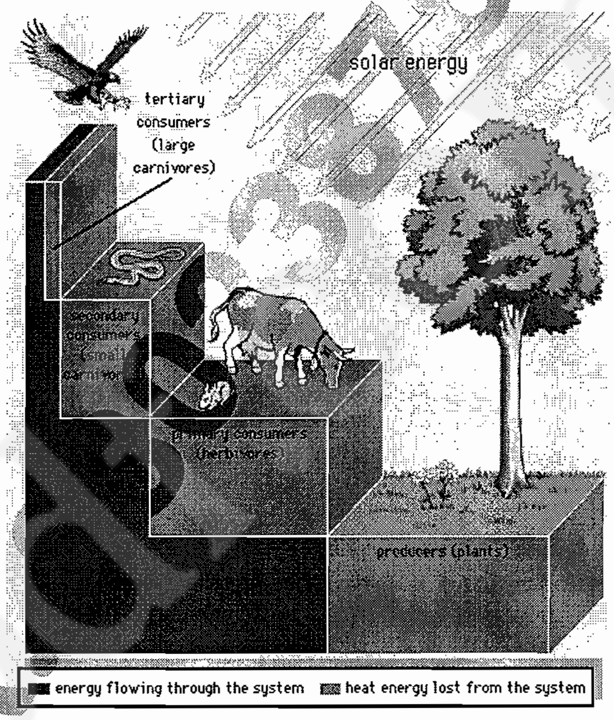


Figure 2: Different Trophic Levels in Biosphere

1. The fundamental source of energy in almost all ecosystems is radiant energy from the sun. The energy of sunlight is used by the ecosystem's autotrophic, or self-sustaining, organisms. Consisting largely of green vegetation, these organisms are capable of photosynthesis—*i.e.*, they can use the energy of sunlight to convert carbon dioxide and water into simple, energy-rich carbohydrates. The autotrophs use the energy stored within the simple carbohydrates to produce the more complex organic compounds, such as proteins, lipids, and starches that maintain the organisms' life processes. The autotrophic segment of the ecosystem is commonly referred to as the **producer level**.

2. Organic matter generated by autotrophs directly or indirectly sustains heterotrophic organisms. Heterotrophs are the consumers of the ecosystem; they cannot make their own food. They use, rearrange, and ultimately decompose the complex organic materials built up by the autotrophs. All animals and fungi are heterotrophs, as are most bacteria and many other microorganisms.

3. Together, the autotrophs and heterotrophs form various trophic (feeding) levels in the ecosystem: the producer level, composed of those organisms that make their own food; the primary-consumer level, composed of those organisms that feed on producers; the secondary-consumer level, composed of those organisms that feed on primary consumers; and so on. The movement of organic matter and energy from the producer level through various consumer levels makes up a food chain. For example, a typical food chain in a grassland might be grass (producer) → mouse (primary consumer) → snake (secondary consumer) → hawk (tertiary consumer). Actually, in many cases the food chains of the ecosystem overlap and interconnect, forming what ecologists call a **food web**.

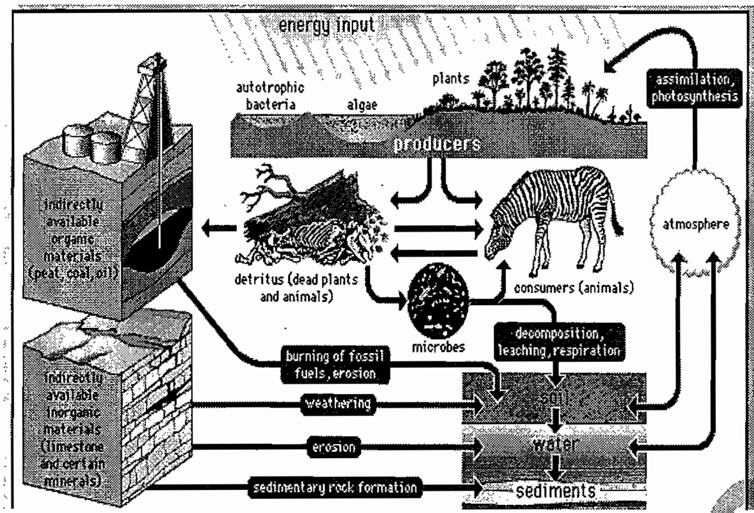


Figure 3: The flow of energy in Ecosystem

4. The final link in all food chains is made up of **decomposers**, those heterotrophs that break down dead organisms and organic wastes. A food chain in which the primary consumer feeds on living plants is called a grazing pathway; that in which the primary consumer feeds on dead plant matter is known as a detritus pathway. Both pathways are important in accounting for the energy budget of the ecosystem.

5. As energy moves through the ecosystem, much of it is lost at each trophic level. For example, only about 10 percent of the energy stored in grass is incorporated into the body of a mouse that eats the grass. The remaining 90 percent is stored in compounds that cannot be broken down by the mouse or is lost as heat during the mouse's metabolic processes. Energy losses of similar magnitude occur at every level of the food chain; consequently, few food chains extend beyond five members (from producer through decomposer), because the energy available at higher trophic levels is too small to support further consumers. The following generalized diagram describes this.

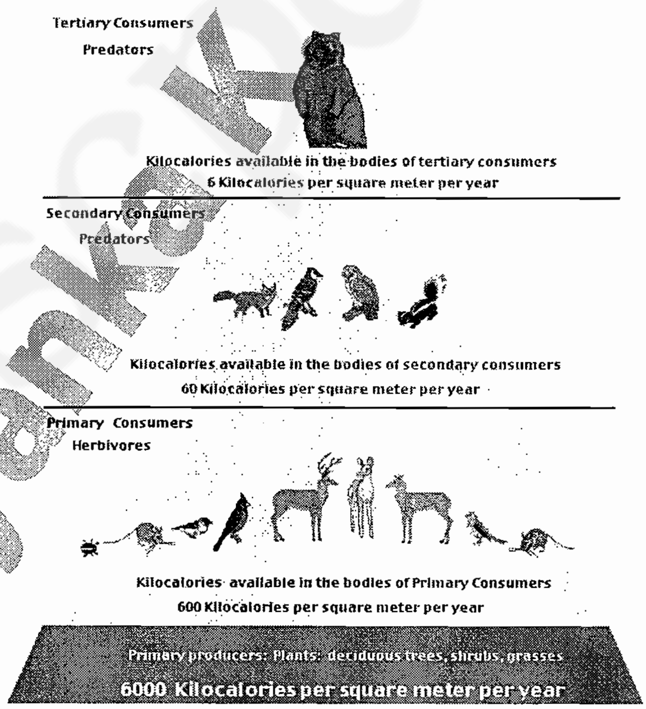


Figure 4: An Ecological Pyramid of Energy

6. The flow of energy through the ecosystem drives the movement of nutrients within the ecosystem. Nutrients are chemical elements and compounds necessary to living organisms. Unlike energy, which is continuously lost from the ecosystem, nutrients are cycled through the ecosystem, oscillating between the biotic and abiotic components in what are called **biogeochemical cycles**. Major biogeochemical cycles include the water cycle, carbon cycle, oxygen cycle, nitrogen cycle, phosphorus cycle, sulfur cycle, and calcium cycle. Decomposers play a key role in many of these cycles, returning nutrients to the soil, water, or air, where they can again be used by the biotic constituents of the ecosystem.

An **ecological pyramid** (or **trophic pyramid**) is a concept related to ecosystem energetics. It is graphical representation designed to show the biomass or productivity at each trophic level in a given ecosystem. *Biomass pyramids* show the abundance or biomass of organisms at each trophic level, while *productivity or energy pyramids* show the production or turnover in biomass. Ecological pyramids begin with producers on the bottom and proceed through the various trophic levels, the highest of which is on top (Figure 3).

Complexity of Ecosystems

Complexity of ecosystems is described in terms of the complexity of biotic composition and the multitude of biological interactions. It has traditionally been accepted that a complex ecosystem is more stable; however it is not always true.

The organisms in an ecosystem are usually well balanced with each other and their environment. This balance is achieved through various types of symbiosis, such as **predation**, **parasitism**, **mutualism**, **commensalism**, **competition**, and **amensalism**.

Analysis of two-species population interactions

Type of interaction	*Species 1*	*Species 2*	*General nature of interaction*
Neutralism	0	0	Neither population affects the other
Competition, direct interference type	–	–	Direct inhibition of each species by the other
Competition, resource use type	–	–	Indirect inhibition when common resource is in short supply
Amensalism	–	0	Population 1 inhibited, 2 not affected
Commensalism	+	0	Population 1, the *commensal*, benefits, while 2, the *host*, is not affected
Parasitism	+	–	Population 1, the *parasite*, generally smaller than 2, the *host*
Predation (including herbivory)	+	–	Population 1, the *predator*, generally larger than 2, the *prey*
Protocooperation	+	+	Interaction favorable to both but not obligatory
Mutualism	+	+	Interaction favorable to both and obligatory

Note: 0 indicates no significant interaction; + indicates growth, survival, or other population attribute benefited (positive term added to growth equation); – indicates population growth or other attribute inhibited (negative term added to growth equation).

Types of ecosystems

Ecosystems can be classified in many different ways and the term itself is used in a variety of contexts. Areas as small as intertidal rock pools and as large as entire rainforests can both be described as ecosystems. However, it is generally not possible to state with precision where one ecosystem ends and another begins. The notion of rigidly separable ecosystems is thus a largely artificial one. **E.P. Odum and GW Barret in the 5th edition (2005) of their classic text *Fundamentals of Ecology* recognise the following major ecosystems.**

Marine ecosystems	Open ocean (pelagic) Continental shelf waters (inshore water) Upwelling regions (fertile areas with productive fisheries) Deep sea (hydrothermal vents) Estuaries (coastal bays, sounds, river mouths, salt marshes)
Freshwater ecosystems	Lentic (standing water): lakes and ponds Lotic (running water): rivers and streams Wetlands: marshes and swamp forests
Terrestrial ecosystems	Tundra: arctic and alpine Boreal coniferous forests Temperate deciduous forests Temperate grassland Tropical grassland and savanna Chaparral: winter rain–summer drought regions Desert: herbaceous and shrub Semi-evergreen tropical forest: pronounced wet and dry seasons Evergreen tropical rain forest
Domesticated ecosystems	Agroecosystems Plantation forest and agroforest systems Rural technoecosystems (transportation corridors, small towns, industries) Urban-industrial technoecosystems (metropolitan districts)

Changes in Ecosystems: Natural

The natural world is in a constant state of flux and ecosystems are no exceptions. However, many ecosystems, when not disturbed by humans, appear superficially to be stable and unchanging, maintained in equilibrium by the "balance of nature". A long term analysis establishes that this is not the case. Actually, longer-term changes—those running over decades, centuries, millennia, and ultimately over tens of millions of years—are difficult to track.

1. On land, temperature, rainfall, and seasonality are the three factors which are most important in determining the distribution of ecosystems. Changes in any one of these can have a lasting effect. In recent geological times the most dramatic example is the series of Ice Ages. It caused the spread of ice cover in temperate areas and the shrinking of moist forest habitats in parts of the tropics.

2. Climatic change with a wide geographical influence can also occur over shorter timescales. One of the most striking examples is El Niño, a cold-water current which periodically sweeps across the Pacific. This has a major impact on marine ecosystems, leading, for example, to the death of reef corals in many parts of the Pacific, and the lowering of fisheries production in the Humboldt Current ecosystem off Chile and Peru. El Niños occur irregularly and vary in intensity and impact; it is rare for more than 20 years to pass without one and occasionally they may be separated by only 1 or 2 years. El Niños also affect terrestrial ecosystems through changing rainfall patterns, particularly in the Americas.

3. Local events can also have major effects on ecosystems: fires, floods, and landslides are all natural events which can have catastrophic local impact. This impact is not necessarily negative: many ecosystems actually require periodic disturbance to maintain themselves. Fire-climax ecosystems, in which periodic burning is an essential part of the growth cycle, are widespread in semi-arid areas such as much of Australia.

4. At longer timescales, geological processes and evolution play a crucial role in changing the functioning of ecosystems. Continental Drift literally changes the face of the planet, creating new landscapes and destroying others; while evolution leads to new life-forms which may themselves create new ecosystems at the same time as leading to the extinction of other species and the loss or transformation of the ecosystems of which they were a part.

However, this is not to mean that there is no continuity in natural ecosystems. Many show great resilience and persistence through periods of many millions of years. Examples of ecosystems which have apparently remained stable for a very long time include those on the vast deep-sea plains, the Mediterranean-type ecosystems of southern Africa and western Australia, and some areas of tropical rainforest, such as those in parts of the south-east Asian mainland and in the mountains of eastern Africa.

Changes in Ecosystems: Man made

All natural environments and ecosystems now have an unprecedented problem to deal with: humanity. Humans have brought about profound changes in a few centuries which would otherwise be expected over thousands or millions of years. The full impact of these remains to be accurately estimated. Major human impacts on ecosystems include the following:

1. Habitat Destruction and Fragmentation

The most direct impact of humans on ecosystems is in their destruction or conversion. Clear-cutting (the cutting of all trees within a given forest area) will, obviously, destroy a forest ecosystem. Selective logging may also alter forest ecosystems in important ways. Fragmentation—the division of a once continuous ecosystem into a number of smaller patches—may disrupt ecological processes so that the remaining areas can no longer function as they once did.

2. Climate Change

It is now widely accepted that humanity's activities are contributing to global warming, chiefly through the accumulation of "greenhouse" gases in the atmosphere. The impact of this is likely to increase in the future. As noted above, climate change is a natural feature of the Earth. Previously, however, its effects were mitigated as ecosystems could effectively "migrate" by moving latitude or altitude as the climate changed. Today, so much of the world's land surface has been appropriated by people that in many cases there is no such place for the remaining natural or semi-natural ecosystems to migrate to.

3. Pollution

Contamination of the natural environment through a range of pollutants—herbicides, pesticides, fertilizers, industrial effluents, and human waste products—is one of the most pernicious forms of impact on the natural environment. Pollutants are often invisible, and the effects of air pollution and water pollution may not be immediately obvious, although they can be devastating in the long run. The impact of acid rain on freshwater and forest ecosystems in much of northern and central Europe is a case in point.

4. Introduced Species

Human beings have been responsible either deliberately or accidentally for altering the distribution of a vast range of animal and plant species. This includes not only domesticated animals and cultivated plants but pests such as rats, mice, and many insects and fungi. Species which become naturalized may have a devastating impact, through predation and competition, on natural ecosystems, particularly on islands where native species have evolved in isolation. For instance, foxes, rabbits, cane toads, feral cats, and even buffaloes and camels have wreaked havoc in many ecosystems in Australia. Plants such as the South American shrub *Lantana* have invaded natural forests in many tropical and subtropical islands, causing major changes to these ecosystems, while the African water hyacinth *Eichhornia* has similarly disrupted freshwater ecosystems in many of the warmer parts of the world.

5. Over-Harvest

Removal of excessive numbers of animals or plants from a system can cause major ecological changes. The most important example of this at present is the over-fishing of the world's oceans. Depletion of the great majority of accessible fish stocks is undoubtedly a cause of major change, although its long-term impact is difficult to assess.

Controlling human impact on ecosystems

Controlling changes in the world's ecosystems may be the major challenge facing human beings in the coming times. Solutions will have to be found at all scales, from the local to the global.

Protection of remaining natural ecosystems in national parks and other protected areas is crucial. However, this will not prevent areas being affected by factors such as climate change, or air- or water-borne pollutants. Moreover, as natural areas shrink in size they are likely to require more and more active management to maintain their ecological functions, for example through control of exotic species, manipulation of water levels in wetlands, or periodic controlled burning in some forest habitats. However, increased intervention of this sort may be risky, as we still do not fully understand the workings of most ecosystems.

Control of pollution and emission of greenhouse gases will require action at the global level, as will efforts to prevent further deterioration of marine fisheries through over-fishing. Ultimately, the solution lies in control of human population growth and in a far more restrained approach to our use of natural resources and expenditure of energy.

Chapter 4: Themes related to ecosystems

Ecological pyramids

Ecological pyramid is a geographical representation of an ecological parameter like number of individuals or amount of biomass or amount of energy present in various trophic levels of a food chain with producer forming the base and top carnivores at the tip.

Ecological pyramids were developed by Charles Elton (1927) and are, therefore, also called Eltonian pyramids. In a pyramid the various steps of a food chain are represented sequences wise with producers at the base, herbivores above them, followed by primary carnivores and so on with carnivores constituting the top of pyramid. An ecological pyramid can be upright, inverted or spindle shaped. Pyramids are usually prepared for three aspects of a food chain or ecosystem number of individuals, amount of biomass and amount of energy.

Types of Ecological Pyramids

There are three types of ecological pyramids:

1. Pyramid of Numbers
2. Pyramid of Biomass
3. Pyramid of Energy

Pyramid of Numbers

It is a graphic representation of the number of individuals per unit area of various trophic levels stepwise with producers being kept at the base and top carnivores kept at the tip. In most cases the pyramid of number is upright with members of successive higher trophic level being less than the previous one. The maximum number of individuals occurs at the producer level. The producers support comparatively fewer numbers of herbivores, the latter fewer number of primary carnivores and so on. Top carnivores are very few in number. In a grassland, a larger number of grass plants or herbs support a fewer number of grasshoppers that support a still smaller number of frogs, the latter still smaller number of snakes and the snakes very few peacocks or falcons. A similar case is found in a pond ecosystem where a large number phytoplankton support comparatively smaller number of zooplanktons the latter fewer number of small-sized fIshes, the small-sized fishes become food of stIll fewer larger-sized fishes or water birds.

The number of pyramids in a higher trophic level is generally smaller than that of the lower trophic level because the organisms of the higher trophic level are dependent for their food and energy on the organisms of the lower trophic level.

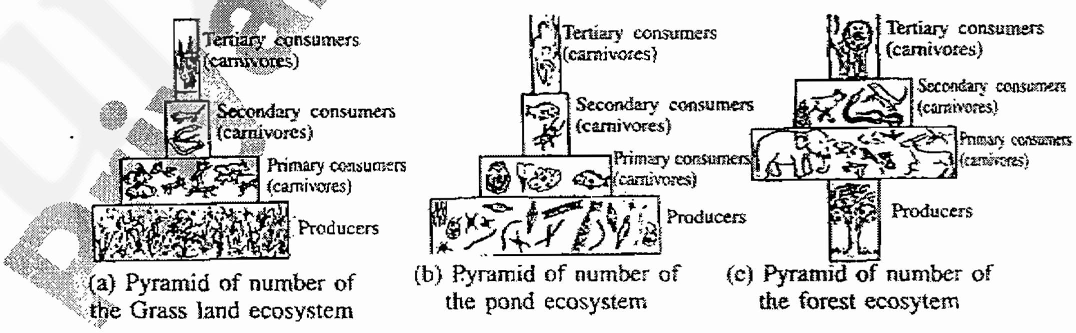


Figure 5: Pyramid of number

Pyramid of Biomass

Pyramid of biomass is a graphic representation of biomass present sequence-wise per/unit area of different trophic levels with producers at the base and top carnivores kept at the tip. Pyramid of biomass is more real than the pyramid of numbers because the pyramid of number does not take into consideration the size of the individual. For example, mouse, shrew, squirrel, rabbit, deer, antelope, bison and elephant are all herbivores. The same amount of vegetation will support a large number of mice, fewer rabbits, still smaller number of deer and very few elephants. However, their total biomass shall be equal and will be related to the biomass of the vegetation as well.

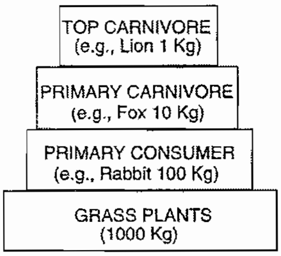


Figure 6: Upright pyramid of biomass for terrestrial habitats.

Maximum biomass occurs in producers. There is a progressive reduction of biomass found in herbivores, primary carnivores, secondary carnivores, etc. It is found that about 10-20% of the biomass is transferred from lower trophic level to hIgher level. The rest is consumed in providing energy for giving heat, overcoming entropy and performing various body activities. Thus 1000 kg of vegetation supports a biomass of only 100 kg of herbivores which in its turn shall form only 10 kg of biomass in the primary carnivore and only 1 kg in secondary carnivore.

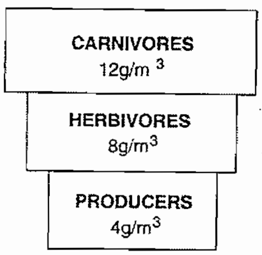


Figure 3: Inverted pyramid of biomass in an aquatic system

Pyramid of biomass is upright for terrestrial habitats. Inverted or spindle-shaped pyramids are obtained in aquatic habitats where the biomass of a trophic level depends upon reproductive potential and longevity of its members. Thus the biomass of phytoplankton may be smaller than that of zooplankton and that of the latter less than of primary carnivores. However, if total biomass produced per unit time is calculated, the pyramid of biomass shall always be upright.

Pyramid of Energy

It is graphical representation of amount of energy trapped per unit time and area in different trophic levels of a food chain with producers forming the base and top carnivorous the tip. The energy content is expressed Kcal/m²/year or KJ/m²/year. Maximum energy content is present in producers. They obtain the energy from solar radiations. The energy is converted in chemical form and stored inside organic matter manufactured by the producers. As the energy passes into higher tropical level along with food, its amount decreases because of its dissipation as head and used in overcoming entropy as well as for performing various body

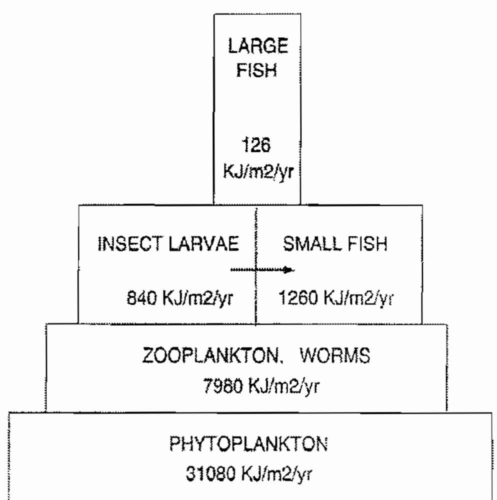


Figure 4: Pyramid of energy in a fish pond

activities.

The data given by Odum (1971) shows that in a fish pond phytoplankton trap 31080 KJ/m²/year of energy. Zooplankton and other herbivores dependent upon phytoplankton have an energy content of 7980 KJ/m²/year. The primary carnivores (incest larvae and small fish) possess an energy content of 2100 KJ/m²/year. They support secondary carnivores with an energy content of 126 KJ/m²/year. If secondary carnivore is eaten by human being only 16.8 KJ/m²/year of energy content is stored. Thus pyramid of energy is always upright. It is more accurate than the pyramid of biomass or the pyramid of numbers.

Limitations of Ecological Pyramids

1. Ecological pyramids assume that food chains are simple. Simple food chains do not occur in nature. Instead food webs are present.
2. A simple species may operate at two or more tropical levels. Ecological pyramids have no method of accommodating such cases.
3. Ecological pyramids have no place for detrivoves and decomposers though they play a vital role in ecosystem.

Food chains

A food chain is sequence of population or organisms of an ecosystem through which the food and its contained energy passes; it is a sequence of the eaters being eaten.

Types of Food Chains

Food chains are of three types:

1. Parasitic,
2. Detritus, and
3. Grazing.

Parasitic Food Chain

Parasitic food chain also called auxiliary food chain; it begins with host and usually ends in parasite.

Detritus Food Chain

Detritus food chain (DFC) begins with detritus or dead organic matter. The food energy present in detritus passes into detrivores and decomposers who feed over it. Detrivores and decomposers are consumed by smaller carnivores which in turn become food for larger carnivores and so on. A common detritus food chain with earthworm as detrivores is

Detritus → Earthworm → Sparrow → Falcon
↘ Frog → Snake → Peacock

Grazing Food Chain

Grazing food chain (GFC) is the most common food chain. It is also called predator food chain as predation occurs at every step. This food chain is consists of producers, consumers and

decomposers. Consumers are often of 3 to 5 types: first order (primary), second order (secondary), third order (tertiary), fourth order (quarternary) consumers.

Producers: They constitute the first trophic level or base of a food chain. Producers are autotrophic organisms which are able to manufacture organic food from inorganic matter and solar radiations. Sunlight is changed into chemical energy by chlorophyll. The chemical energy is used in converting raw materials into organic food. Oxygen is evolved in the process.

$$6CO_2 + 6H_2O \xrightarrow[enzyme]{light,\ chlorophyll} C_6H_{12}O_6 + 6O_2$$

Organic food synthesized by producers consists of all essential ingredients like carbohydrates, fats, proteins, vitamins, etc. It contains energy. Part of the food manufactured by the producers is used up by themselves in providing energy for various body activities and in overcoming entropy. The rest is used in their body building and storage. Part or whole of the stored food enters the food chain as food for consumers. Producers are also known as transducers because they are able to change radiant or light energy into chemical form.

Primary Consumers or Herbivores: They are animals which feed on plants or plant products, e.g., grasshoppers and several other insects, rabbit, hare, field mouse, deer, antelope, elephant, zooplankton (Paramecium, Daphnia, and some larvae), tadpoles, some fishes. A part of plant food eaten by herbivores become constituent of their body while a major part is consumed by them is used in production of energy for various body activities. Herbivores are also called key industry animals because they convert plant matter into animal matter.

Secondary Consumers or Primary Carnivores: They ingest or prey upon herbivorous animals, e.g. frog, predator insects, several birds, fishes, wild cat, fox, jackal (also scavenger), etc. A part of flesh or food obtained from herbivore is used in body building by primary carnivores while the rest is consumed in providing energy for various life processes.

Tertiary Consumers or Secondary Carnivores: They are larger carnivores which prey upon primary carnivores e.g, wolf (feed on fox), snake (prey upon frog).

Top Carnivores: They are the last order consumers or carnivores which are not preyed upon by other animals because of their size, agility and ferociousness, e.g., shark, crocodile, eagle, peacock, tiger, lion.

A food chain may terminate at the level of herbivore (e.g. vegetation → elephant), primary carnivore (e,g., vegetation → squirrel → bear) secondary carnivores (vegetation → squirrel → wild cat → tiger), tertiary carnivore etc.

Examples of some common food chains.

1. Grass → Grass Hopper → Frog → snake → Peacock/Falcon.
2. Vegetation → Rabbit → Fox → Wolf → Tiger
3. Vegetation → Insect → Predator Insect → Insectivorous Bird → Hawk.

Example of Food Chains in Water (Pond)

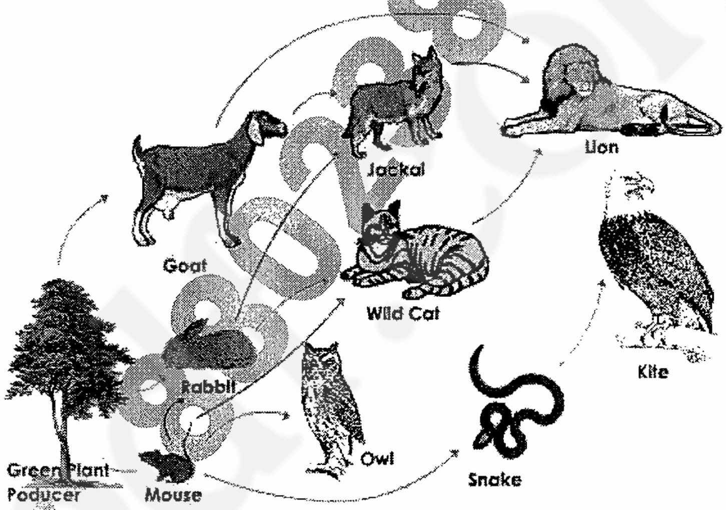
1. Phytoplankton → Zooplankton → Small Crustaceans → predator Insects → Small Fish → Larger Fish → Crocodile.

2. Phytoplankton → Zooplankton → small Crustaceans → Predator Insects → Small Fish → Kind fisher/Stork.

Food Web

It is a network of food chains which interconnect various trophic levels and form a number of feeding connections amongst the different organisms of a biotic community. Food web increases the stability of an ecosystem by providing alternate sources of food and allowing the endangered population to grow in size.

The pioneering animal ecologist Charles Elton (1927) introduced the concept of the food web (which he called food cycle. As he described it: " There are, in fact, chains of animals linked together by food, and all dependent in the long run upon plants. We refer to these as 'food-chains', and to all the food chains in a community as the 'food-cycle.'"



Food Web in a Forest

Composition of Food Web

A food web operates according to food preferences of the organisms at each trophic level. However, availability of food source and other compulsions are equally important. In Sunderbans, the tigers eat fish and crab in the absence of their natural preys. Some organism normally operates at more than one trophic level. Thus human beings are not only herbivores but also carnivores of various levels. Jackals are both carnivores and scavengers. Snakes feed on mice (herbivores) as well as frogs (carnivores). Wild cats prey upon mice as well as birds and squirrels. A wolf eats fox as well as rabbit and deer. Therefore, the concept of food web appears more real ecologically than the concept of a simple food web in maintaining stability of ecosystem is given below.

A herbivore like rabbit does not get starved if its preferred plant species is reduced in quantity due to some calamity. It begins feeding on alternate plant species. The preferred one gets chance to recover from the loss. Similarly, rabbits are preyed upon by foxes, wild dogs, wild cats, jackals, etc. In case the population of rabbit decreases, the predators begin to eat mice, shrews, squirrels, etc. Meanwhile rabbits increase their population and restore the balance.

Difference between Food Chain and Food Web

Food Chain	Food Web
1. It is a straight single pathway through which food energy travels in the ecosystems	1. It consists of number of interconnected food chain through which food energy passes in the ecosystems.
2. Members of higher trophic level feed upon a single type of organisms of lower trophic level.	2. Members of higher trophic level can feed upon a number of alternative organisms of the lower trophic level
3. Presence of separate or isolated food	3. Presence of food webs increases the

chains adds to the instability of the ecosystem.	stability of the ecosystem
4. It does not add to adaptability and competitiveness of the organisms.	4. Food webs increase adaptability and competitiveness of the organisms

A short description of Grassland Ecosystem

Grassland is a type of terrestrial ecosystem. Grasslands occupy a comparatively fewer area, roughly 19% of the earth's surface. Typical features of grassland are the lack of long trees and big bushes. Grassland is characterized by the average rain fall of between 250 and 900 mm per year. If a grassland receives rain fall more than this average they will slowly turn into forests and if they receive less, they will gradually turn into deserts.

Grasslands across World

Grasslands are found in all continents and abundantly in the North and South Americas, Africa, Asia and Australia. Only place where grasslands are not found at all is the Antarctica. Despite of their well characterized presence all over the world, grasslands are known by many different names throughout the world. They are known as "prairie" in North America, "steppe" in Asia, "pampas" in South America and a "veldt" in South Africa.

Abiotic Component of Grassland Ecosystem

The abiotic components of a grassland ecosystem are the non-living features of the ecosystem on which living organisms depend. These are nutrients present in soil and the aerial environment.

Thus, the elements like C, H, O, N, P, S etc. are supplied by carbon dioxide, water, nitrates, phosphates and sulphates etc., present in air and soil of the grassland. Moreover, in addition to the above, some trace elements are also present in soil. Soil is a vital link between the biotic and abiotic parts of a grassland ecosystem.

Average daily temperatures range between -20 and 30 °C. Temperate grasslands have warm summers and cold winters with rain or some snow.

Biotic Component of Grassland Ecosystem

The biotic components of a grassland ecosystem are the living organisms that exist in the system. These organisms can be classified as producers, consumers or decomposers.

Producers are able to capture the sun's energy through photosynthesis and absorb nutrients from the soil, storing them for future use by themselves and by other organisms. Grasses, shrubs, trees, mosses, lichens, and cyanobacteria are some of the many producers found in a grassland ecosystem. When these plants die they provide energy for a host of insects, fungi and bacteria that live in and on the soil and feed on plant debris. Grasses are an important source of food for large grazing animals such as Sheep, Deer and smaller animals such as mice.

Consumers are organisms that do not have the ability to capture the energy produced by the sun, but consume plant and/or animal material to gain their energy for growth and activity. Consumers are further divided into three types based on their ability to digest plant and animal material:

- Herbivores: Rabbit, mice, sheep, deer, etc.
- Carnivores: Frog, Snake, Eagle, ect.

Decomposers include the insects, fungi, algae and bacteria both on the ground and in the soil that help to break down the organic layer to provide nutrients for growing plants. There are millions of these organisms in each square metre of grassland.

Plant and Animal Life in Grassland Ecosystem

Grassland Animals: All grasslands have the common features of having plenty of grass as food and lacking cover from predators. Hence the types of animals that inhabit the grasslands around the world are similar, being predominantly plant eating or herbivorous ungulates, which are animals that have long legs and hoofs, like deer and horses, which enable them to outrun their predators.

Some of the animals that belong to the temperate grasslands of North America are: coyotes, prairie dogs, gophers, antelope, bison, eagles, wild turkey, Canadian geese, bobcats, the gray wolf, fly catchers, and various types of insects. There are similar animals that inhabit the steppes, such as foxes, falcons, antelopes, and the lynx.

Grassland Plants: Grasses are the type of plants that predominate the temperate grasslands. Shrubs and trees occur very rarely in this biome. There are several types of grasses that grow in the grassland biome, such as buffalo grass, ryegrass, foxtail, wild oats, and purple needlegrass. Although animals feed on these grasses, they can survive because the point of growth of the grasses is very near the surface of the ground. Besides, they survive even fires due to the underground buds and stems. The trees and shrubs that grow in the grassland biome, on the other hand, are easily destroyed in fires.

A short description of Pond Ecosystem

Ecosystem is the basic functional unit which deals with ecology. It includes both the organisms and non living environment, each influencing the properties of the other and both are necessary for the maintenance of life on earth.

A pond ecosystem is a fresh water ecosystem where communities of organism dependent on each other with the water environment for their nutrients and survival. Usually ponds are shallow water bodies with a depth of 12-15 feet in which the sun rays can penetrate to the bottom permitting the growth of plants.

Functional Component of Pond Ecosystem

Abiotic Components

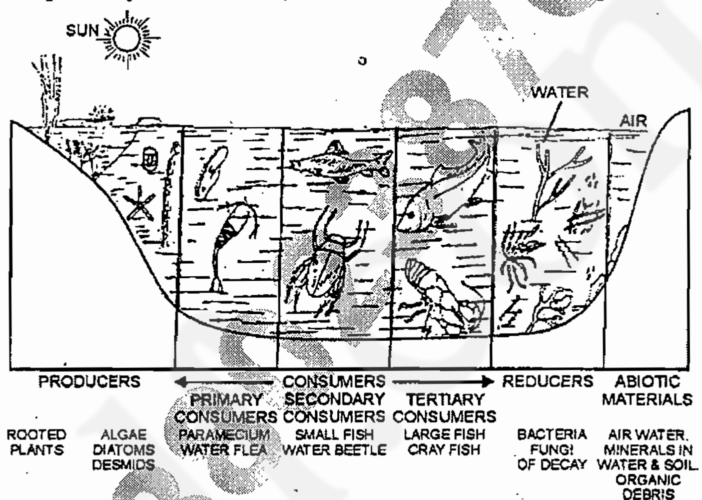
The abiotic substances of pond ecosystem are formed as a result of the mixture of some organic and inorganic materials. The basic components are water, oxygen, carbon dioxide, salts of calcium and nitrogen etc. Only a small amount of these elements are present in soluble state in pond water, but a large amount is held in reserve solid form in the bottom sediments as well as within the organisms. Various organisms get their nourishment from these abiotic substances. The rate of release of reserve nutrients, the solar input and the cycle of temperature, day length and other climatic conditions regulate the function of the pond ecosystem.

Biotic Components

The biotic components of Pond ecosystem consists of –

Producers: The producers are of two types; larger rooted and floating vegetations together termed macrophytes and phytoplanktons. Phytoplanktons are available up to the depth of water where light penetrates. The phytoplanktons are filamentous alga like *Ulothrix, Oedogonium, Spirogyra, Anabena, Oscillatoria* and minute floating plants like *Microcystis, Gloeotrichina volvox* etc. The macrophytes include marginal emergent plants like *Typha* , *Acerus, Ipomea,* submerged plants like *Hydrilla, Utricularia, Trapa, Nymphea* etc; surface floating plants like *Pistea, Lemna, Wolffia, Eichhornia, Salvinia* etc.

Consumers: Consumers of pond ecosystem are heterotrophs which depend for their nutrition on other organisms. Zooplanktons form primary consumers, include *Brachionus, Asplanchna, Lechane,* (rotofers) *Colops, Dilepteus, Cyclops, Stenocypris* (crustacean), who feed on phytoplankton. Nectic animals like insects, beetles, fishes form secondary consumers as they feed on zooplanktons. Benthic animals like snakes, big fishes live on nectic animals and are termed tertiary consumers.



Decomposers: Most of the decomposers of Pond ecosystem are saprophytes but some parasites are also found. Bacteria, fungi like *Aspergillus, Cladosporium, Rhizopus, Alternaria, Fusarium, Saprolegnia* etc are decomposers. Generally the decomposers either live in the soil layer beneath water or in the mud. They act on dead and decayed organic matter of plants and animals and supply raw materials to the producers.

Energy Flow in Pond Ecosystem

Phytoplanktons are the producers of pond ecosystem along with other floating plants. The energy produced by the autotrophs are passed through food chain. In pond the larvae of insects consume autotrophs as food. So according to law of energy flow the larvae assimilate energy from autotrophs. So larvae are primary consumers. These primary consumers are taken as food by prawns, small carnivorous fishes etc and so they collect energy from larvae. They are, therefore secondary consumers. Large fishes consume secondary consumers, and are tertiary consumers.

Chapter 5. Biogeochemical Cycles

What is a Biogeochemical Cycle?

The chemical elements, including all the essential elements of life, tend to circulate in the biosphere in characteristic pathways from environment to organisms and back to the environment. These more or less circular pathways are known as **biogeochemical cycles.**

In other words, a biogeochemical cycle is a circuit or pathway by which a chemical element or molecule moves through both biotic ("bio-") and abiotic ("geo-") compartments of an ecosystem. In effect, the element is recycled, although in some such cycles there may be places (called "sinks") where the element is accumulated or held for a long period of time. The movement of these elements and inorganic compounds that are essential to life can be conveniently designated as **nutrient cycling**. The dissipation of energy in some form is always necessary to drive material cycles.

All chemical elements occurring in organisms are part of biogeochemical cycles. In addition to being a part of living organisms, these chemical elements also cycle through abiotic factors of ecosystems such as water (hydrosphere), land (lithosphere), and the air (atmosphere); the living factors of the planet can be referred to collectively as the biosphere. All the chemicals, nutrients, or elements—such as carbon, nitrogen, sulfur , phosphorus—used in ecosystems by living organisms operate on a **closed system**, which refers to the fact that these chemicals are recycled instead of being lost and replenished constantly such as in an open system.

Basic Terms

Sink: In a biogeochemical cycle, the element is recycled, but in some such cycles there may be places where the element is accumulated or held for a long period of time. Such places are called **sinks**. Such a place is also called a **reservoir**.

Exchange pools: When chemicals are held for only short periods of time, they are said being held in **exchange pools**.

Generally, reservoirs are abiotic factors while exchange pools are biotic factors. Examples of exchange pools include plants and animals, which temporarily use carbon in their systems and release it back into the air or surrounding medium. On the other hand, coal deposits are the reservoirs or sinks of carbon. Carbon is held for a relatively short time in plants and animals when compared to coal deposits.

Residence: The amount of time that a chemical is held in one place is called its residence.

Parts of a Biogeochemical Cycle

Based on the above terminology, each cycle is divided into two compartments or pools:

(1) the reservoir pool, the large, slow-moving, generally nonbiological component; and

(2) the labile or cycling pool, a smaller but more active portion that is exchanging rapidly between organisms and their immediate environment. Many elements have multiple reservoir pools, and some (such as nitrogen) have multiple labile pools.

Types of Biogeochemical Cycles

From the viewpoint of the ecosphere as a whole, biogeochemical cycles fall into two basic groups:

(1) Gaseous types, in which the reservoir is in the atmosphere or the hydrosphere (ocean); and

(2) Sedimentary types, in which the reservoir is in the crust of earth.

Biogeochemical cycles are also classified on the basis of the chemical being in the cycle. The most important cycles include:

1. Carbon Cycle
2. Nitrogen Cycle
3. Oxygen Cycle
4. Sulfur Cycle
5. Phosphorus Cycle
6. Hydrological Cycle

Carbon cycle

Introduction

The **carbon cycle** is the biogeochemical cycle by which carbon is exchanged between the biosphere, geosphere, hydrosphere and atmosphere of the Earth.

The cycle has four major reservoirs of carbon interconnected by pathways of exchange. The reservoirs are:

(1) the atmosphere

(2) the terrestrial biosphere (which usually includes freshwater systems and non-living organic material, such as soil carbon)

(3) the oceans (which includes dissolved inorganic carbon and living and non-living marine biota

(4) the sediments (which includes fossil fuels).

The annual movements of carbon, the carbon exchanges between reservoirs, occur because of various chemical, physical, geological, and biological processes.

Parts of the Cycle

In the atmosphere

Carbon exists in the Earth's atmosphere primarily as the gas carbon dioxide (CO_2). Although it is a very small part of the atmosphere overall (approximately 0.037% on a molar basis and rising), it plays an important role in supporting life. Other gases containing carbon in the atmosphere are methane and chlorofluorocarbons (the latter is entirely artificial). These are all greenhouse gases whose concentration in the atmosphere has been increasing in recent decades, contributing to global warming.

Carbon is taken from the atmosphere in several ways:

- When the sun is shining, plants perform photosynthesis to convert carbon dioxide into carbohydrates, releasing oxygen in the process. This process is most prolific in relatively new forests where tree growth is still rapid.

- At the surface of the oceans towards the poles, seawater becomes cooler and CO_2 is more soluble. This is coupled to the ocean's thermohaline circulation which transports dense surface water into the ocean's interior.

- In upper ocean areas of high productivity, organisms form tissue containing reduced carbon, and some also form carbonate shells, tests, or other hard body parts. These are, respectively, oxidized (soft-tissue pump) and redissolved (carbonate pump) at lower average levels of the ocean than those at which they formed, resulting in a downward flow of carbon.

Carbon can be released back into the atmosphere in many different ways,

- Through the respiration performed by plants and animals. This is an exothermic reaction and it involves the breaking down of glucose (or other organic molecules) into carbon dioxide and water.

- Through the decay of animal and plant matter. Fungi and bacteria break down the carbon compounds in dead animals and plants and convert the carbon to carbon dioxide if oxygen is present, or methane if not.

- Through combustion of organic material which oxidizes the carbon it contains, producing carbon dioxide (as well as other things, like smoke). Burning fossil fuels such as coal, petroleum products, and natural gas releases carbon that has been stored in the geosphere for millions of years. This is a major reason for rising atmospheric carbon dioxide levels.

- Production of cement. A component, lime, is produced by heating limestone, which produces a substantial amount of carbon dioxide.

- At the surface of the oceans where the water becomes warmer, dissolved carbon dioxide is released back into the atmosphere

- Volcanic eruptions and metamorphism release gases into the atmosphere. These gases include water vapor, carbon dioxide and sulfur dioxide. The carbon dioxide released is roughly equal to the amount removed by silicate weathering; so the two processes, which are the chemical reverse of each other, sum to roughly zero, and do not affect the level of atmospheric carbon dioxide on time scales of less than about 100,000 yr.

In the Biosphere

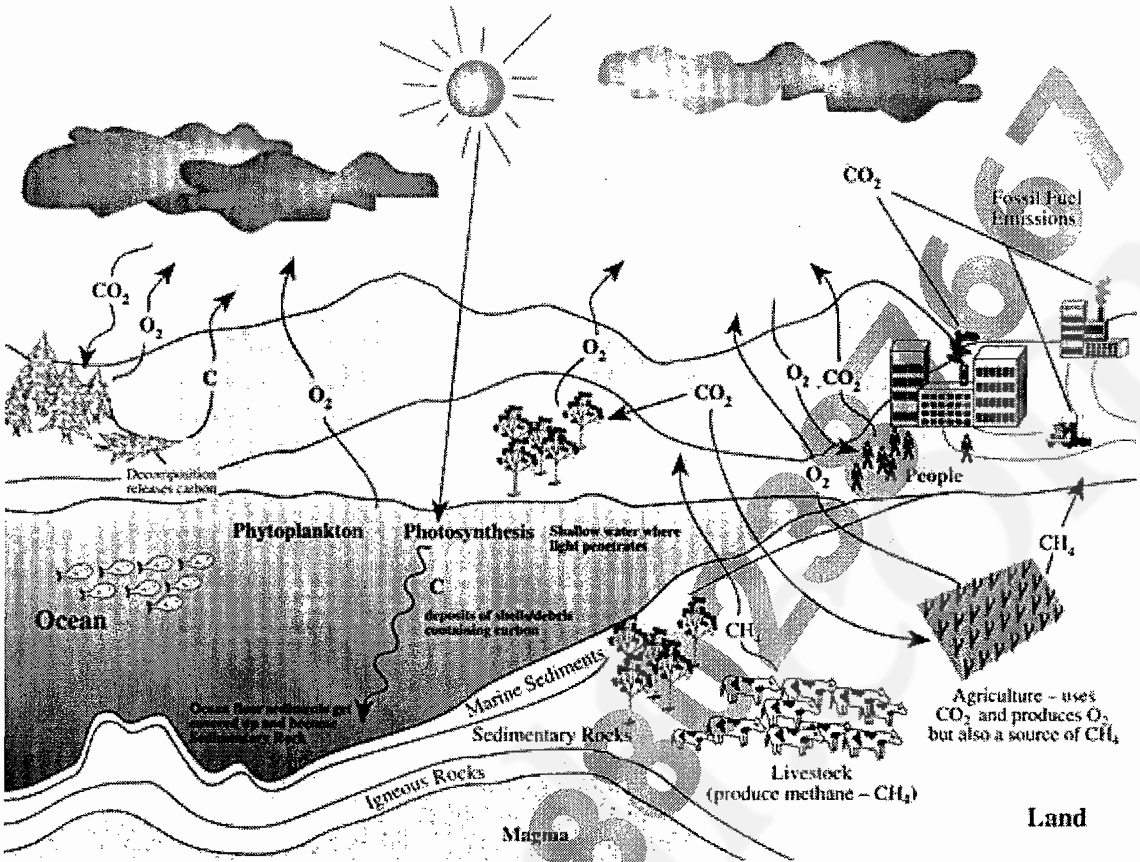
Around 2100 gigatonnes of carbon are present in the biosphere. Carbon is an essential part of life on the Earth. It plays an important role in the structure, biochemistry, and nutrition of all living cells, and life plays an important role in the carbon cycle:

- Autotrophs are organisms that produce their own organic compounds using carbon dioxide from the air or water in which they live. To do this they require an external source of energy. Almost all autotrophs use solar radiation to provide this, and their production process is called photosynthesis. A small number of autotrophs exploit chemical energy sources, chemosynthesis. The most important autotrophs for the carbon

cycle are trees in forests on land and phytoplankton in the Earth's oceans. Photosynthesis follows the reaction $6CO_2 + 6H_2O \rightarrow C_6H_{12}O_6 + 6O_2$

- Carbon is transferred within the biosphere as heterotrophs feed on other organisms or their parts (e.g., fruits). This includes the uptake of dead organic material (detritus) by fungi and bacteria for fermentation or decay.
- Most carbon leaves the biosphere through respiration. When oxygen is present, aerobic respiration occurs, which releases carbon dioxide into the surrounding air or water, following the reaction $C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O$. Otherwise, anaerobic respiration occurs and releases methane into the surrounding environment, which eventually makes its way into the atmosphere or hydrosphere.
- Burning of biomass (e.g. forest fires, wood used for heating, anything else organic) can also transfer substantial amounts of carbon to the atmosphere
- Carbon may also be circulated within the biosphere when dead organic matter (such as peat) becomes incorporated in the geosphere. Animal shells of calcium carbonate, in particular, may eventually become limestone through the process of sedimentation.
- Much remains to be learned about the cycling of carbon in the deep ocean. For example, a recent discovery is that larvacean mucus houses (commonly known as "sinkers") are created in large numbers and they can deliver a large amount of carbon to the deep ocean.

Carbon storage in the biosphere is influenced by a number of processes on different time-scales: while Net primary productivity follows a diurnal and seasonal cycle, carbon can be stored up to several hundreds of years in trees and up to thousands of years in soils. Changes in those long term carbon pools (e.g. through de- or afforestation or through temperature-related changes in soil respiration) will thus directly affect global warming.



In the Ocean

The seas contain around 36000 gigatonnes of carbon, mostly in the form of bicarbonate ion. Inorganic carbon, that is carbon compounds with no carbon-carbon or carbon-hydrogen bonds, is important in its reactions within water. This carbon exchange becomes important in controlling pH in the ocean and can also vary as a source or sink for carbon. Carbon is readily exchanged between the atmosphere and ocean. In regions of oceanic upwelling, carbon is released to the atmosphere. Conversely, regions of downwelling transfer carbon (CO_2) from the atmosphere to the ocean. When CO_2 enters the ocean, carbonic acid is formed:

$$CO_2 + H_2O \rightleftharpoons H_2CO_3$$

This reaction has a forward and reverse rate, that is it achieves a chemical equilibrium. Another reaction important in controlling oceanic pH levels is the release of hydrogen ions and bicarbonate. This reaction controls large changes in pH:

$$H_2CO_3 \rightleftharpoons H^+ + HCO_3^-$$

Human Impact

Felling of forests, coal-burning power plants, automobile exhausts, factory smokestacks, and other waste vents of the human environment contribute about 22 billion tons of carbon dioxide (corresponding to 6 billion tons of pure carbon) and other greenhouse gases into the earth's atmosphere each year. This alters the Carbon Cycle drastically. The atmospheric concentration of CO_2 has increased by 31% above pre-industrial levels since 1750. This is considerably higher

than at any time during the last 420,000 years, the period for which reliable data has been extracted from ice cores.

According to a report in the *New Scientist*, new data from US National Oceanic and Atmospheric Administration (NOAA) show that the amount of CO_2 in the atmosphere in 2003 reached an all time high of 376 parts per million (ppm). In the late 1950s, average levels were around 315 ppm. Overall, the concentration of CO_2 in the atmosphere has increased by 31% since 1750, i.e. since the Industrial Revolution. **Carbon dioxide emissions are now around 12 times higher than in 1900** as the world burns increased quantities of coal, oil and gas for energy.

This serious imbalance in the Carbon cycle is responsible behind the phenomena like Green House Effect, Global Warming and Climate Change. It is now an established fact that these environmental anomalies will have disastrous consequences for the entire biosphere and humanity.

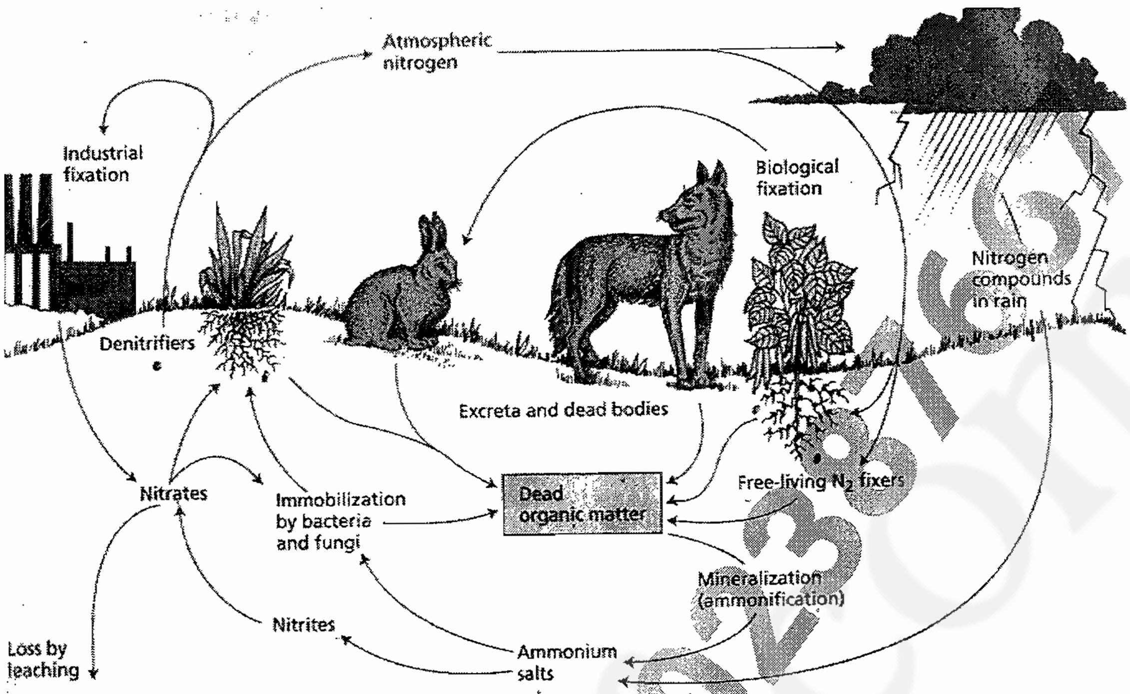
Cycling of Nitrogen

Introduction

The growth of all organisms depends on the availability of mineral nutrients, and nitrogen is one of the most important among them, which is required in large amounts as an essential component of proteins, nucleic acids, coenzymes, vitamins and other cellular constituents. Nitrogen is essential for many biological processes; it is in all amino acids, is incorporated into proteins, and is present in the bases that make up nucleic acids, such as DNA and RNA. In plants, much of the nitrogen is used in chlorophyll molecules which are essential for photosynthesis and further growth (Smil, 2000).

There is an abundant supply of nitrogen in the earth's atmosphere - nearly 79% in the form of N_2 gas.

The **nitrogen cycle** is the biogeochemical cycle that describes the transformations of nitrogen and nitrogen-containing compounds in nature.



Parts of the Cycle

Earth's atmosphere is about 79% nitrogen, making it the largest pool of nitrogen. However, N_2 is unavailable for use by most organisms because there is a triple bond between the two nitrogen atoms, making the molecule almost inert. In order for nitrogen to be used for growth it must be "fixed" (combined) in the form of ammonium (NH_4) or nitrate (NO_3) ions.

Six processes participate in the cycling of nitrogen through the biosphere:

- nitrogen fixation
- decay
- nitrification
- denitrification
- Anammox
- Leaching and weathering of rocks

Nitrogen Fixation

Nitrogen fixation is the process by which nitrogen is taken from its relatively inert molecular form (N_2) in the atmosphere and converted into nitrogen compounds useful for other chemical processes (such as, notably, ammonia, nitrate and nitrogen dioxide).

Three processes are responsible for most of the nitrogen fixation in the biosphere.

- Atmospheric fixation by lightning
- Biological fixation by certain microbes – free living or in a symbiotic relationship with plants

- Industrial fixation by Haber and Bosch Process

Type of fixation	N_2 fixed (10^6 metric tons per year)
Non-biological	
Industrial	about 50
Combustion	about 20
Lightning	about 10
Total	**about 80**
Biological	
Agricultural land	about 90
Forest and non-agricultural land	about 50
Sea	about 35
Total	**about 175**

Atmospheric Fixation

The enormous energy of lightning breaks nitrogen molecules and enables their atoms to combine with oxygen in the air forming nitrogen oxides. These dissolve in rain, forming nitrates, which are carried to the earth.

Atmospheric nitrogen fixation probably contributes some 5% of the total nitrogen fixed.

Industrial Fixation by Haber & Bosch Process

Under great pressure, at a temperature of 600°C, and with the use of a catalyst, atmospheric nitrogen and hydrogen (usually derived from natural gas or petroleum) can be combined to form ammonia (NH_3). Ammonia can be used directly as fertilizer, but most of it is further processed to urea and ammonium nitrate (NH_4NO_3).

Industrial nitrogen fixation probably contributes some 20% of the total nitrogen fixed.

Biological Fixation

Nitrogen fixation is performed biologically by a number of different prokaryotes, including bacteria, and actinobacteria certain types of anaerobic bacteria. Many higher plants, and some animals (termites), have formed associations with these microorganisms. *No eukaryotic organism known so far has the nitrogen fixing ability.*

Biological nitrogen fixation requires a complex set of enzymes and a huge expenditure of ATP. The most fundamental enzyme required for nitrogen fixation is **Nitrogenase**, which is present only in the **diazotrophic** (nitrogen fixing) bacteria.

There are four groups of diazotrophic (nitrogen fixing) bacteria. Important diazotrophs are listed below.

I. Free Living Nitrogen Fixers: Aerobes

1. Cyanobacteria

Anabaena, Nostoc, Gloeotheca, Calothrix

2. Chemoorganotrophs

Azotobacter, Azomonas, Agrobacterium, Klebsiella (Facultative), *Beijerinckia, Bacillus polymyxa* (Facultative), *Azospirillum, Citrobacter*

3. Chemolithotrophs

Alcaligens, Thiobacillus

II. Free Living Nitrogen Fixers: Anaerobes

1. Chemoorganotrophs

Clostridium, Desulfovibrio

2. Phototrophs

Chromatium, Ectothiorhodospira, Thiocapsa, Chlorobium, Chlorobaculum

3. Archaea

Methanococcus, Methanosarcina, Methanobacterium

Symbiotic Nitrogen Fixers: Non Leguminous Host

1. ***Frankia*:** Wide host range in many tree species of angiosperms, such as *Alnus, Casuarina, Colletia, Coriaria, Myrica, Discaria, Rubus, Cowania, Purshia* and some shrubs like, *Datisca, Coenothus* and *Cercocarpus ledifolius.*
2. ***Acetobacter*:** Sugar cane
3. ***Nostoc*:** the hornwort *Anthoceros*, the liverwort *Porella*, the lichen *Lobaria pulmonaria*
4. ***Anabaena*:** the fern *Azolla*
5. ***Nostoc*:** *Gunnera* (forming petiolar nodules)
6. ***Nostoc*:** The palm *Welfia regia*

Symbiotic Nitrogen Fixers: Leguminous or some closely related Host

By 5 genera of closely related diazotrophs: *Rhizobium, Azorhizobium, Bradyrhizobium, Photorhizobium, Sinorhizobium*

Whether symbiotic or free living, the enzymology and biochemistry of Nitrogen Fixation is the same. Some bacteria, called Diazotrophs, convert N_2 into ammonia by the enzyme termed **Nitrogense Complex.** Biological nitrogen fixation can be represented by the following equation, in which two moles of ammonia are produced from one mole of nitrogen gas, at the expense of 16 moles of ATP and a supply of electrons and protons (hydrogen ions):

$$N_2 + 8H^+ + 8e^- + 16\ ATP = 2NH_3 + H_2 + 16ADP + 16\ Pi$$

Although the first stable product of the process is ammonia, this is quickly incorporated into protein and other organic nitrogen compounds.

Decay

Decay (also called Ammonification or Mineralization) is carried out by a number of microbes and some fungi. The proteins made by plants enter and pass through food webs just as carbohydrates do. At each trophic level, their metabolism produces organic nitrogen compounds that return to the environment, chiefly in excretions and also as a part of the dead remains of the organism.. The final beneficiaries of these materials are microorganisms of decay. They break down the molecules in excretions and dead organisms into ammonia.

Nitrification

Ammonia can be taken up directly by plants — usually through their roots. However, most of the ammonia produced by decay is converted into **nitrates**. This is accomplished in two steps:

- Bacteria of the genus **Nitrosomonas** and **Nitrococcus** oxidize NH_3 to **nitrites** (NO_2^-).
- Bacteria of the genus **Nitrobacter** oxidize the nitrites to **nitrates** (NO_3^-).

These two groups or autotrophic bacteria are called **nitrifying bacteria**. Through their activities (which supply them with all their energy needs as these bacteria are Chemoautotrophs), nitrogen is made available to the roots of plants. **Most of the rooted land plants get their nitrogen in the form of Nitrate ions**, as shown in the figure of nitrogen cycle. This is due to intense competition within the soil for any other form of fixed Nitrogen.

Denitrification

Denitrification reduces nitrates to nitrogen gas, thus replenishing the atmosphere. Once again, bacteria are the agents, for example *Thiobacillus denitrificans, Bacillus denitrificans* and some species of *Pseudomonas*, *Alkaligenes* and *Bacillus*.

Anammox

Anammox -acronym for anaerobic ammonium oxidation- is the latest addition to the knowledge on the nitrogen cycle. In this biological process, nitrite and ammonium are converted directly into dinitrogen gas. This process makes up a major proportion of dinitrogen conversion in the oceans. The overall catabolic reaction is[1]:

$NH_4^+ + NO_2^- \rightarrow N_2 + 2H_2O$.

The bacteria that perform the anammox process belong to the rare order of the planctomycetes, of which planctomyces and pirellula are the most important members. Current anammox genera are: *Brocadia, Kuenenia, Anammoxoglobus* (all fresh water species), and Scalindua (marine species). Of special interest is the turnover of hydrazine (normally known as rocket fuel, and poisonous to most living organisms) as an intermediate. Another striking feature of the organism is the extremely slow growth rate, with the doubling time of nearly two weeks.

Leaching and Weathering of Rocks

A small amount of Nitrate is leached down to ground water deposits causing pollution. The situation is aggravated by indiscriminate use of nitrogen fertilizers. Excess nitrate in drinking water is dangerous for human health and may be fatal for infants. It reacts with haemoglobin and forms nonfunctional **methaemoglobin** that impairs oxygen transport. This is called **methaemoglobinemia** or **blue-baby syndrome**.

The weathering of rocks releases fixed nitrogen ions into the soil but so slowly that it has a negligible effect on the availability of fixed nitrogen.

Human Impact on the Cycle

Humans have contributed significantly to the nitrogen cycle by artificial nitrogen fertilization (primarily through the Haber process, using energy from fossil fuels to convert N_2 to ammonia gas (NH_3) and planting of nitrogen fixing crops (Vitousek *et al.*, 1997). In addition, humans have significantly contributed to the transfer of nitrogen trace gases from Earth to the atmosphere. N_2O has risen in the atmosphere as a result of agricultural fertilization, biomass burning, cattle and feedlots, and other industrial sources (Chapin *et al.* 2002). N_2O has deleterious effects in the stratosphere, where it breaks down and acts as a catalyst in the destruction of atmospheric ozone. NH_3 in the atmosphere has tripled as the result of human activities. It is a reactant in the atmosphere, where it acts as an aerosol, decreasing air quality and clinging on to water droplets, eventually resulting in acid rain. Fossil fuel combustion has contributed to a 6 or 7 fold increase in NOx flux to the atmosphere. NO actively alters atmospheric chemistry, and is a precursor of tropospheric (lower atmosphere) ozone production, which contributes to smog, acid rain, and increases nitrogen inputs to ecosystems (Smil, 2000). Ecosystem processes can increase with nitrogen fertilization, but anthropogenic input can also result in nitrogen saturation, which weakens productivity and can kill plants (Vitousek *et al.*, 1997). Decreases in biodiversity can also result if higher nitrogen availability increases nitrogen-demanding grasses, causing a degradation of nitrogen-poor, species diverse heathlands (Aerts and Berendse 1988).

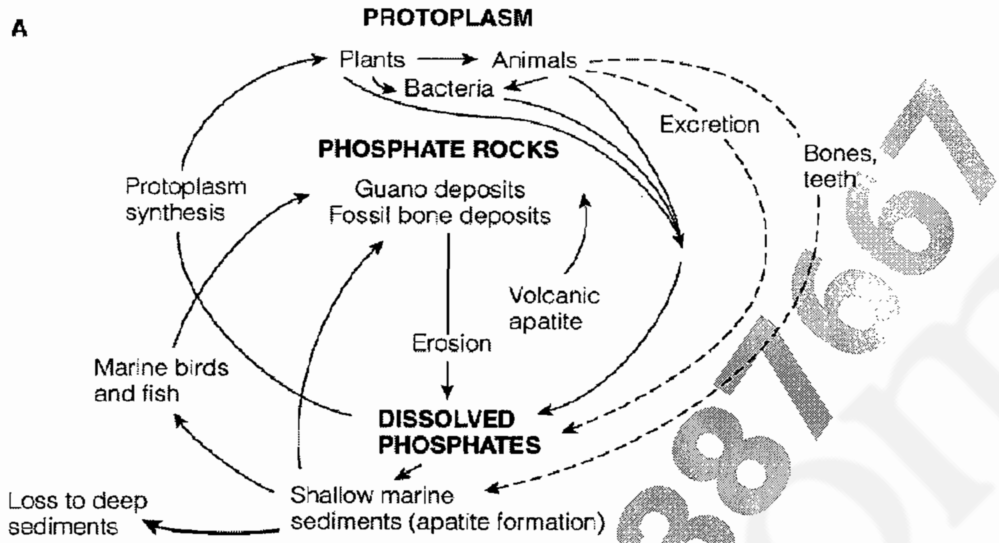
Cycling of Phosphorus

Introduction

Phosphorus is an essential nutrient for plants and animals in the form of ions PO_4^{3-} and HPO_4^{2-}. It is a part of DNA-molecules, of molecules that store energy (ATP and ADP) and of fats of cell membranes. Phosphorus is also a building block of certain parts of the human and animal body, such as the bones and teeth.

Phosphorus can be found on earth in water, soil and sediments. *Unlike the compounds of other matter cycles phosphorus cannot be found in air in the gaseous state.* It is mainly cycling through water, soil and sediments. In the atmosphere phosphorus can mainly be found as very small dust particles.
Phosphorus moves slowly from deposits on land and in sediments, to living organisms, and then much more slowly back into the soil and water sediment. *The phosphorus cycle is the* slowest one of the matter cycles.

The phosphorus cycle appears somewhat simpler than the nitrogen cycle, because phosphorus occurs in fewer chemical forms.



Parts of the cycle

As shown in the figure here, phosphorus, a necessary constituent of protoplasm, tends to circulate with organic compounds in the form of phosphates (PO_4), which are again available to plants.

The great reservoir of phosphorus is in apatite mineral deposits formed in past geological ages (that is, in the lithosphere).

Seabirds (Seabirds are birds that have adapted to life within the marine environment) play a limited role in returning phosphorus to the cycle (as shown by the guano deposits located on the coast of Peru). This transfer of phosphorus and other materials by birds from the sea to the land is continuing, likely at the same rate at which it occurred in the past – but these guano deposits have been mined out.

Human Influence

Human influences on the phosphate cycle come mainly from the introduction and use of commercial synthetic fertilizers. The phosphate is obtained through mining of certain deposits of calcium phosphate called apatite. It depletes the long term phosphate deposits.

Plants may not be able to utilize all of the phosphate fertilizer applied, as a consequence, much of it is lost form the land through the water run-off. The phosphate in the water is eventually precipitated as sediments at the bottom of the body of water. In certain lakes and ponds this may be redissolved and recyled as a problem nutrient.

Sulfur cycle

Introduction

Sulfur, the 14th most abundant element in the Earth's crust, is not only a critical component of essential biological compounds such as the amino acids cysteine and methionine, its cycle, like that of nitrogen, plays a substantial role in the regulation of other nutrients, including oxygen and phosphorus. The heart of the sulfur cycle involves the uptake of sulfate by producers, largely through their roots, and the release and transformation of the sulfur in a number of different

steps and variety of forms, including sulfhydryl (-SH), hydrogen sulfide (H_2S), sulfites (SO)), and molecular sulfur (S). Like the nitrogen cycle, the sulfur cycle is complex.

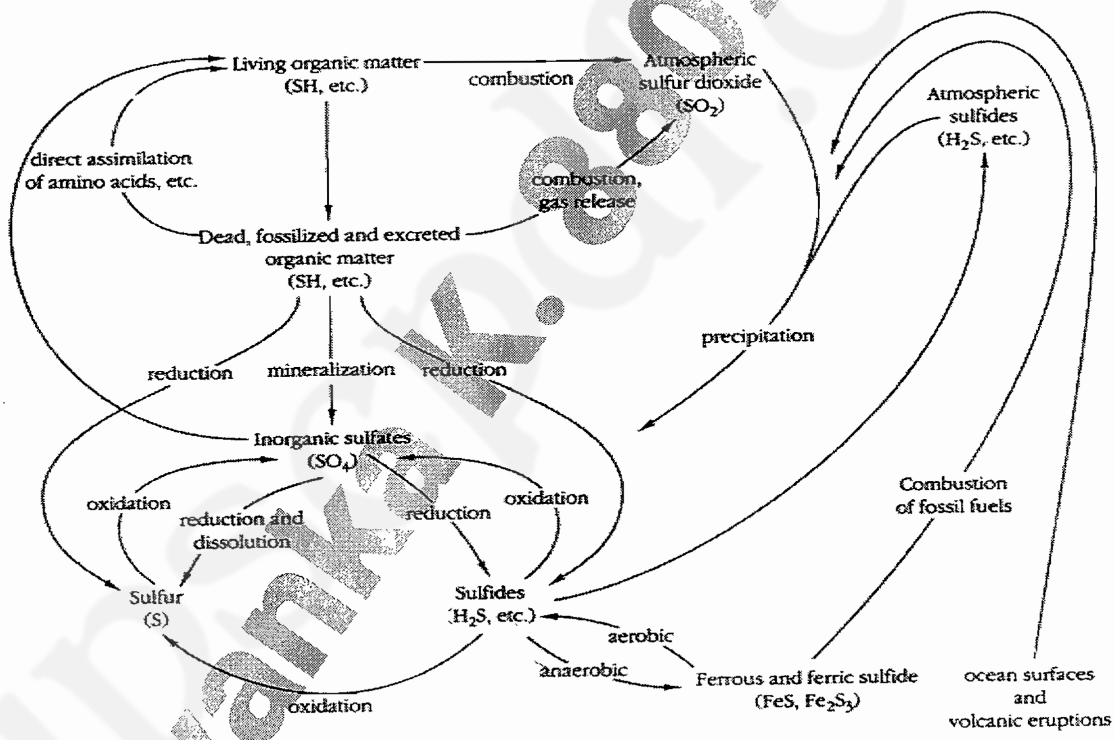
An important distinction between cycling of sulfur and cycling of nitrogen and carbon is that sulfur is "already fixed". That is, plenty of sulfate anions (SO_4^{2-}) are available for living organisms to utilize. By contrast, the major biological reservoirs of nitrogen atoms (N_2) and carbon atoms (CO_2) are gases that must be pulled out of the atmosphere.

Parts of the Cycle

The sulfur cycle can be studied according to different locations of the cycling process as it is done below. Important reactions of the sulfur cycle include the following.

Sulfur Cycle in Soils

Sulfur enters the trophic cycle in terrestrial plants via root adsorption in the form of inorganic sulfates (e.g., calcium sulfate, sodium sulfate) or by direct assimilation of amino acids released in the decomposition of dead or excreted organic matter. Bacterial and fungal *(Aspergillus* and *Neurospora)* mineralization of the organic sulfhydryl in amino acids followed by oxidation results in sulfate; this adds to the sulfate pool for root adsorption.



Under anaerobic conditions, sulfuric acid may be reduced directly to sulfides, including hydrogen sulfide, by such bacteria as *Escherichia* and *Proteus.* Sulfate is also reduced under anaerobic conditions to elemental sulfur or to sulfides, including hydrogen sulfide, by such heterotrophic bacteria as *Desulfovibrio,* as well as by *Escherichia* and *Aerobacter.* These sulfate reducing anaerobic bacteria are heterotrophic, using the sulfate as a hydrogen acceptor in metabolic oxidation in a manner comparable to the use of nitrite and nitrate by de nitrifying bacteria.

Sulfate reduction generally occur only under anaerobic conditions. However, Canfield and Des Marais (1991) found that sulfate reduction occurs in the upper, well-oxygenated, photosynthetic zone of hypersaline microbial mats from Baja California, Mexico. Thus, sulfate reduction is not strictly an anaerobic process.

The presence of large quantities of hydrogen sulfide in the anaerobic, and usually deeper, portions of aquatic ecosystems is harmful to most life. But, when present, the filamentous bacterium *Beggiatoa* significantly reduces hydrogen sulfide levels.

The existence of archaebacterial sulfate reducers *(Methanobacterium thermautotrophicum* and *Methanococcus thermolithotrophicus)* at extremely high temperatures (70°C to 100°C) can explain the formation of hydrogen sulfide observed in submarine hydrothermal systems, deep oil wells, and fumaroles (steam vents) (Stetter et al. 1987). A more recent study has demonstrated sulfate reaction near hydrothermal vents at temperatures up to 100°C with an optimum rate between 103° to 106°C by hyperthermophilic bacteria.

Colorless sulfur bacteria, such as species of *Beggiatoa,* oxidize hydrogen sulfide to elemental sulfur, and species of *Thiobacillus* oxidize it to sulfate; other species of *Tbiobacillus* oxidize sulfide to sulfur, and still others oxidize sulfur to sulfate. For some species, even those of the same genus, the oxidation processes can occur only in the presence of oxygen; for others, oxygen availability is irrelevant. These latter bacteria are chemosynthetic autotrophs, using the energy liberated in the oxidation to obtain their needed carbon by reduction of carbon dioxide:

$$6\,CO2 + 12\,H_2S \rightarrow C_6\,H_{12}O_6 + 6\,H_2O + 12\,S$$

These bacteria are thus comparable to the chemosynthetic autotrophic nitrifying bacteria that oxidize ammonia to nitrite and nitrite to nitrate. In addition, they also include the green and purple photosynthetic bacteria that use the hydrogen of hydrogen sulfide as the oxygen acceptor in reducing carbon dioxide. The green bacteria apparently are able to oxidize sulfide only to elemental sulfur, whereas the purple bacteria can carry the oxidation to the sulfate stage:

$$6\,CO_2 + 12\,H_2O + 3\,H_2S \rightarrow C_6H_{12}O_6 + 6\,H_2O + 3\,SO_4^= + 6\,H^+$$

Sulfur Cycle in Atmosphere

Sulfur in the atmosphere comes from several different sources: decomposition and/or combustion of organic matter, combustion of fossil fuels, and ocean surfaces and volcanic eruptions. The most prevalent form of sulfur entering the atmosphere is sulfur dioxide (SO_2). It, along with other atmospheric forms such as elemental sulfur and hydrogen sulfide, is oxidized to sulfur trioxide (SO_3), which combines with water to form sulfuric acid (H_2SO_4), leading to **acid rain**.

Atmospheric sulfur, largely in the form of sulfuric acid, is removed by two general processes: *rainout,* which includes all processes within clouds that result in removal; and *washout,* which is the removal by precipitation below the clouds. Depending on the amount of the various sulfur compounds available to form the sulfuric acid, the degree of acidity can be strong enough to approximate that of battery acid. Atmospheric inputs of sulfuric acid provide the dominant source of both hydrogen ions (H^+) for cation replacement.

Sulfur in Sediments

The sedimentary aspect of the cycle involves the precipitation of sulfur in the presence of such cations as iron (Fe) and calcium (Ca) as highly insoluble ferrous sulfide (FeS) and ferric sulfide (Fe_2S_3, pyrite) or relatively insoluble calcium sulfate ($CaSO_4$).

The oxidation of sulfides in marine sediments is a key process, though poorly understood.

Human Impact on the Cycle

Both the nitrogen and the sulfur cycles are increasingly being affected by industrial air pollution. The gaseous oxides of nitrogen and sulfur are toxic to varying degrees. Normally, they are only transitory steps in their respective cycles; in most environments, they are present in very low concentrations. The combustion of fossil fuels, however, has greatly increased the concentrations of these volatile oxides in the air, especially in urban areas and in the vicinity of power plants, to the point where they adversely affect important biotic components and processes of ecosystems. When plants, fish, birds, or microbes are poisoned, humans eventually are also adversely affected.

Coal-burning emissions and automobile exhaust are major sources of SO_2 and SO_4 production and, along with other industrial combustion, a major source of poisonous forms of nitrogen. Sulfur dioxide is damaging to photosynthesis, as was discovered in the early 1950s when leafy vegetables, fruit trees, and forests showed signs of stress in the Los Angeles Basin. The destruction of vegetation around copper smelters is largely caused by SO_2. Furthermore, both sulfur and nitric oxides interact with water vapor to produce droplets of dilute sulfuric and nitric acid (H_2SO_4 and H_2NO_3) that fall to Earth as **acid rain**, a truly alarming development. Acid rain has the greatest impact on soft-water lakes or streams and already acidic soils that lack pH buffers (such as carbonates, calcium, salts, and other bases). Acid rain damages building materials. Our heritage monuments (such as Taj Mahal at Agra) are threatened by the corrosive action of acid deposition. Acid rain adversely affects terrestrial and aquatic vegetation. Most planktons, molluscs and fry young fish cannot tolerate water having pH below 5.0. Low pH conditions also damage soil microbial community.

Chapter 6: Community Ecology

Introduction to an ecological community

No ecological process occurs in isolation and each is manifested by particular assemblages of different species populations in particular physicochemical environments. An *ecological community* can be regarded as an assemblage of species populations that has the potential of interaction. More precisely, **a community may be defined as an interactive assemblage of species occurring together within a particular geographical area, a set of species whose ecological function and dynamics are in some way interdependent** (Putman 1994).

Some examples of these interactions include:

1. Overt and critically determining competitive interaction and feeding relationships
2. Subtle interactions, such as reliance of plants on animals for pollination and seed dispersal or of animals on plants for meeting habitat requirements.

Communities are invariable discrete units. Commonly their boundaries merge imperceptibly along environmental gradients, forming an ever-changing complex which is defined as an *ecocline*.

Characteristics of a Community

Hanson and Churchill (1961) classify the properties of a community into two major groups which are further split up into minor groups.

1. Analytic Characteristics

1.1. Qualitative characteristics

***Floristic composition of a community*:** It includes in identifying all the plants (which are the primary producers) that grow in a particular stand or a community. Usually vascular plants are identified but in some localities e.g. the alpine and arctic regions lower groups like mosses and lichens are also collected and identified. Such a list is important to study the inter-relationships of each species to its environment and to its neighbouring species. It also enables us to determine the specific diversity in a plant community. There are some species that are indicators of soil, altitude and micro-climatic conditions and serve to give a very useful data. Their total number also gives us an idea of their abundance in a particular site or area. There is generally a decrease in number from one to the other. This tells us about increasingly adverse conditions.

***Stratification*:** It has also been observed in a natural forest community that the trees, shrubs and herbs appear to be differentiated into several storeys, layers or strata. There appear to be well defined strata for the tallest trees which tend to stand singly or in groups above a more or less continuous main canopy; below this may be successively small trees, shrub and herbaceous layers. The several strata are composed each of a separate group of species. This phenomenon in a forest community is called stratification. A typical Indian example of stratification can be seen in a wet evergreen tropical forest. In such a forest from Andaman Island, the top storey or stratum is made usually of scattered tall tress of *Dipterocarpus grandiflorus* and *D. pilosus*. This is followed by a second storey of small trees and shrubs of *Xanthochymus andamanica*, *Myristica andamanica* etc. The third stratum is composed of *Anaxagorea luzoniensis*. The fourth storey is

made up of herbs like *Dinochloa andamanica*, *Calamus palustris* etc. There are many such examples of stratification throughout India. The trees that form the upper stratum or uppermost canopy are called **dominant trees**. The dominants include **predominants** that are tallest and **codominants** that are a little shorter, but the two together form upper stratum. The trees that form three quarters the height of the predominants are called **dominated** trees. *They fill up the minor holes in the dominanat canopy*. The trees that are a little more than half the height of predominants and stand under the shade of the taller trees are called **suppressed trees.**

Periodicity: This includes the study of various vital processes such as photosynthesis, growth, pollination, reproductive processes, development of leaves, flowers, dissemination of seeds and elongation of shoots in the various seasons of the year in the dominant species of a community. These entire phenomena depend upon the *inheritance* and various *physiological and environmental constellations of factors* operating upon a particular species. The recurrence of these important life phenomena at regular intervals in a year and their manifestation in nature is termed as periodicity.

Vitality: It may be defined as the general condition of the plant and its capacity to reproduce and complete its life cycle under the existing conditions of the environment. Depending upon vitality, species in a community may be classified as:

1. **Perennials** or well developed plants that reproduce well and successfully complete their life cycle.

2. **Ephemerals** or **Adventives** that occasionally appear from seeds and do not increase in number.

3. Plants that spread vegetatively and are unable to complete their life cycles. They are feebly developed.

4. **Vigorous plants** that grow vigorously only during a particular season and are usually unable to complete their life cycle. They may reproduce vegetatively and are of sporadic occurrence.

Sociability or Gregariousness: It refers to the proximity among the members of a community towards one another. This gregariousness or sociability of the species depends upon a uniformity of environmental factors, vigour, dispersal and pollination mechanisms, and methods of reproduction. Sociability of the species can be rated by making following observation.

1. Whether the species grow singly or in groups?

2. The groups of species may be smaller or in scattered tufts.

3. The species may grow in large patches.

4. The species form very large stands or communities of nearly pure populations e.g. *Typha* grows in pure large stands in marshy grounds.

Interspecific Associations: This is the study of two or more species interacting together in a community.

Theoretically, populations of two species may interact in basic ways that correspond to combinations of neutral, positive, and negative (0, +, and -) as follows: 00, - -, + +, + 0, - 0, and + -. Three of these combinations (+ +, - -, and + -) are commonly subdivided, resulting in nine

important interactions and relationships. The terms applied to these relationships in the ecological literature are as follows.

1. **neutralism,** in which neither population is affected by association with the other;
2. **competition, direct interference type,** in which both populations actively inhibit each other;
3. **competition, resource use type,** in which each population adversely affects the other indirectly in the struggle for resources in short supply;
4. **amensalism,** in which one population is inhibited and the other not affected;
5. **commensalism,** in which one population is benefited, but the other is not affected;
6. **parasitism;** and
7. **predation,** in which one population adversely affects the other by direct attack but nevertheless depends on the other;
8. **protocooperation** (also frequently referred to as *facultative cooperation),* in which both populations benefit by the association but their relations are not obligatory; and
9. **mutualism,** in which the growth and survival of both populations is benefited, and neither can survive under natural conditions without the other.

Analysis of two-species population interactions

Type of interaction	*Species 1*	*Species 2*	*General nature of interaction*
Neutralism	0	0	Neither population affects the other
Competition, direct interference type	−	−	Direct inhibition of each species by the other
Competition, resource use type	−	−	Indirect inhibition when common resource is in short supply
Amensalism	−	0	Population 1 inhibited, 2 not affected
Commensalism	+	0	Population 1, the *commensal,* benefits, while 2, the *host,* is not affected
Parasitism	+	−	Population 1, the *parasite,* generally smaller than 2, the *host*
Predation (including herbivory)	+	−	Population 1, the *predator,* generally larger than 2, the *prey*
Protocooperation	+	+	Interaction favorable to both but not obligatory
Mutualism	+	+	Interaction favorable to both and obligatory

Note: 0 indicates no significant interaction; + indicates growth, survival, or other population attribute benefited (positive term added to growth equation); − indicates population growth or other attribute inhibited (negative term added to growth equation).

Three trends in the occurrence of these relationships are especially worthy of emphasis:

- Negative interactions tend to predominate in pioneer communities or in disturbed conditions where r-selection counteracts high mortality.

- In the evolution and development of ecosystems (succession), negative interactions tend to be minimized in favor of positive interactions that enhance the survival of the interacting species in mature or crowded communities.

- Recent or new associations are more likely to develop severe negative interactions than are older associations.

Life forms: In general a life form can be defined as the characteristic vegetative appearance of plant regarding its shape, size, crown, histological features, modes of branching and its life span. **Raunkiaer** defined it as the form based on the location of the overwintering parts. Genetic constitution and the environmental factors operating in an individual determine its life form.

Raunkiaer classified vegetational life forms on the basis of temperature and position of buds in plants. Based on temperature he classified vegetation of the world into four main classes.

(a) **Megatherms** that require constant and high temperature for their growth throughout the year.

(b) ***Mesotherms*** are those plants that can tolerate low temperature for a longer or shorter period of the year. Such plants can usually grow well in tropical and subtropical regions.

(c) ***Microtherms*** are the plants that grow well under low temperatures and cannot tolerate high temperatures. Such plants grow in temperate regions.

(d) ***Hekistotherms*** grow in alphine and arctic regions and require a constant low temperature for their growth.

Regarding the position of buds (plant's embryonic or regenerating (meristematic) tissue), Raunkiaer classified the vegetation of the world into five classes.

1. Phanerophytes: surviving buds or shoot-apices borne on negatively geotropic shoots that project into the air; shrubs and trees. The phanerophytes are further sub-divided into four types depending upon their size:-

    a. Mega-phanerophytes: include trees more than 30 metres high.

    b. Meso-phanerophytes: include trees that are 8-30 metres high.

    c. Nano-phanerophytes: are below two metres in height.

2. Chamaephytes: surviving buds or shoot-apices borne on shoots very close to but above the ground; creeping woody plants and herbs.

3. Hemicryptophytes: surviving buds or shoot-apices are situated at the soil surface protected by leaf and stem bases; herbs growing in rosettes and tussocks.

4. Cryptophytes: surviving buds or shoot-apices are buried in the ground at a distance from the surface that varies indifferent species; tuberous and bulbous herbs.

5. Therophytes: plants of the summer or of the favorable season; overwinter as seeds; annuals.

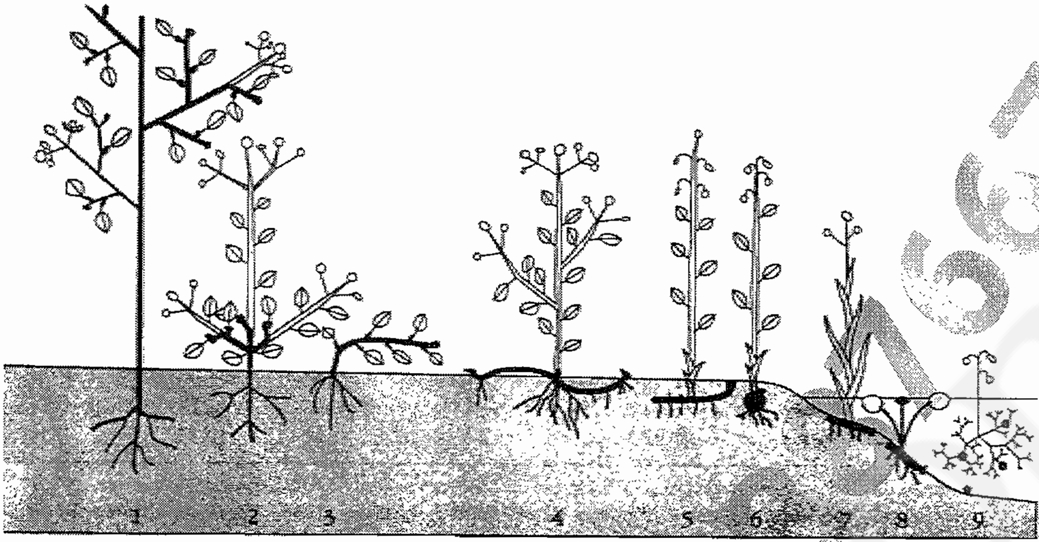


Figure 12-1 Four of Raunkiaer's five life forms: phanerophytes (1), chamaephytes (2–3), hemicryptophytes (4), and cryptophytes (5–9). The parts of the plant unfavorable seasons are unshaded; the persisting parts with surviving buds are shaded black. (Redrawn by permission from C. Raunkiaer. 1934. *The Life-Form of Plants and Statistical Plant Geography*. Oxford: Clarendon Press.)

Raunkiaer used the term **Biological spectrum** or **Phyto-climatic spectrum** to express the percentage of distribution of a species among the life form of a flora. Biological spectrum is very useful in comparing plant communities of the world e.g. the hemicryptophytes are predominant in the grasslands, the therophytes dominate the tropical deserts, whereas the chamaephytes flourish well in the alpine and arctic regions of the world. Raunkiaer postulated the basic idea that same type of the forms predominate under identical environments. He devised the term **equiconditional regions** for such zones.

Braun Blanquet (1951) modified Raunkiaer's classification and proposed the following scheme.

1. **Phytoplankton:-** Including microsopic forms that grow suspended in air, snow or water surface.

2. **Phytoedaphon:-** Include microscopic soil forms.

3. **Endophytes:-** Include plants that grow within the bodies of other plants e.g. some algae and fungi.

4. **Theorphytes:-** Include annuals e.g. algae, liverwords, mosses, ferns and some seed plants.

5. **Hydrophytes:-** that grow in water.

6. **Geophytes:-** Including plants with perennating structures buried under the soil.

7. **Hemicryptophytes:-** described above

8. **Chamaephytes:-** described above.

9. **Epiyhytes:-** Include plants that grow on other plants.

Food Chains: The idea of food chains and food webs was developed in the 1920s by an Oxford biologist, Charles Elton. A careful study of any community will reveal the presence of both producers and consumers. The green plants are the producers whereas the herbivorous and carnivorous animals are the consumers. They form a food chain and the interlinking of several food chains gives rise to a food web. A Food Web is set of interconnected food chains by which energy and materials circulate within an ecosystem. The food chains are variable depending upon the diversity in the floristic composition of a community and variations of the fauna.

The food web can be viewed not only as a network of chains but also as a series of trophic (nutritional) levels. Green plants, primary producers of food, belong to the first trophic level. Herbivores, consumers of green plants, belong to the second trophic level. Omnivores, consumers of both plants and animals, belong to the second and third. Carnivores, predators feeding upon the herbivores, belong to the third. Secondary carnivores, which are predators that feed on predators, belong to the fourth trophic level. As the trophic levels rise, the predators become fewer, larger, fiercer, and more agile. At the second and higher levels, decomposers of the available materials function as herbivores or carnivores depending on whether their food is plant or animal material.

Energy flow in a community: Through these series of steps of eating and being eaten, energy flows from one trophic level to another. Green plants or other photosynthesizing organisms use light energy from the Sun to manufacture carbohydrates for their own needs. Most of this chemical energy is processed in metabolism and dissipated as heat in respiration. Plants convert the remaining energy to biomass, both above ground as woody and herbaceous tissue and below ground as roots. Ultimately, this material, which is stored energy, is transferred to the second trophic level, which comprises grazing herbivores, decomposers, and detrital feeders. Most of the energy assimilated at the second trophic level is again lost as heat in respiration, as energy used for movement, and energy is lost as waste in faeces or undigested material which is not passed on to the next trophic level; a fraction becomes new biomass. Organisms in each trophic level pass on as biomass much less energy than they receive.

The decomposers break down the bodies of the animals and plants when they die, releasing and utilizing much of the energy stored within them. Decomposers also act on the faeces produced by animals, making use of this energy too.

In general, the more steps between producer and final consumer, the less energy remains available. Seldom are there more than four links, or five levels, in a food web. Eventually, all energy flowing through the trophic levels is dissipated as heat. The process whereby energy loses its capacity to do useful work is called entropy.

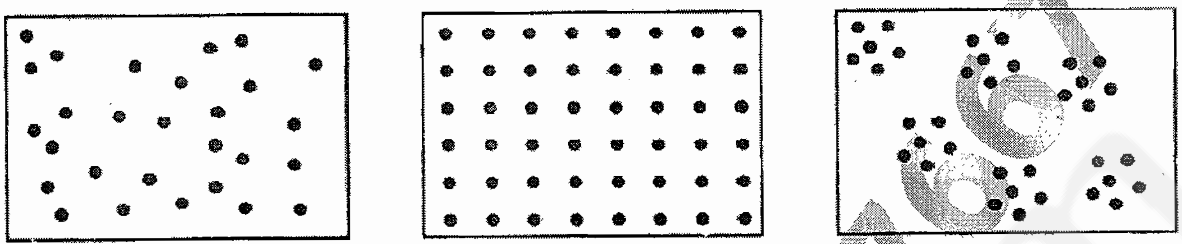
Zonation. Horizontal changes in the physical environment are reflected in zonational changes in plant and animal components of ecological communities. Zonation determines the ***horizontal spacing***, or *dispersion*, of plants and / or animals can also be used to describe the structure of an ecological community. There are three basic patterns of dispersal.

A. Random

B. Uniform or Regular

C. Clumped or Contagious

Two additional patterns exist in combinations of random and clumped, and uniform and clumped.



A. Random B. Uniform C. Clumped

Although a community may show truly random distribution, more often a number of factor results in various degrees of clumping (or contagion), regularity in spacing, or a combination of both. Most often, a clumping of resources (e.g., water, nutrients) leads to clumping of organisms; reproductive patterns may also account for clumping. The availability of a resource, such as groundwater, or the release of biological inhibitors by sedentary plants (a phenomenon known as **allelopathy**) may inhibit other individuals of the species from developing within the radius of the inhibitor's effect; both situations can change the dispersal of that species.

1.2. Quantitative Characteristics

Population density: It refers to the number of individuals of a species per unit of space. When a measured unit area is divided by the number of individuals, the average area occupied by each individual is calculated. Factors that govern the density of population are called **density governing factors e.g.** light, precipitation, soil and resources etc. The factors that do not influence density are called **non-reactive factors e.g.** CO_2 content of the atmosphere. Knowledge of population density is indispensable in studying:

A. The relative importance of each species in a community especially when they are identical in respect of their life, form and size.

B. The effect of reseeding.

C. The effect of burning.

D. The effect of spraying.

E. The effect of successional changes.

Cover: This includes the study of area covered by the foliage, stems and inflorescences of plants as seen from above. While conducting such a study each stratum of vegetation is considered separately. The top layer which is made up of tall plants is considered separately from the second, third and fourth types of strata in a forest community. The term basal area is employed to denote the area of the ground covered by the crown only.

Canopy coverage is the per cent of ground covered by the canopy and can also be expressed as leaf area index (LAI)), i.e.

$$LAI = \frac{\text{Total leaf area (one surface only)}}{\text{Unit ground area}}$$

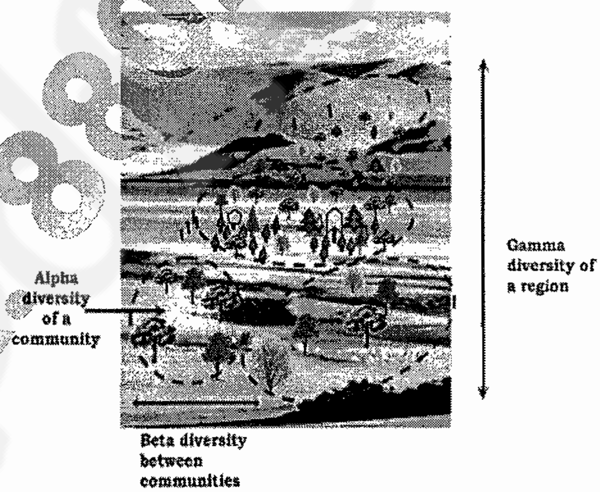
Many crops such as corn have a LAI of about 4, meaning that for every square meter of ground, $4m^2$ of leaves lie above it.

This is the method by which forests are surveyed across the world, including India. Nowadays, remote sensing is employed in this exercise. In India, Dense Forest means canopy coverage of more than 40% of the land area; Open Forest means canopy coverage of 10 – 40% of the land area and Scrubs (and Mangroves) have less than 10% canopy coverage with respect to the total land area.

***Species composition*:** The species composition of a community is also extremely important, because communities are partly defined on a floristic basis. Several communities may belong to the same vegetation type (that is, have similar physiognomies), yet differ in the identity of dominants or other species. The abundance, importance, or dominance of each species can be expressed numerically, so that different communities can be compared on the basis of species similarities and differences.

The relative spatial arrangement of species within a community is another community trait. Individuals within a species or individuals of different species may be distributed at random with respect to each other, clumped (positive interactions) or over-dispersed (negative interactions).

Species Richness, Evenness and Diversity*: *Species richness is the number of species in a community. Each species is not likely, however, to have the same number of individuals. One species may be represented by 1000 plant, another by 200 and a third only a single plant. The distribution of individuals among the species is called ***species evenness*** or ***species equitability***. Evenness is a maximum when all species have the same number of individuals. The inverse of evenness is ***concentration of individuals***.



Species diversity is a product of richness and evenness; it is species richness weighted by species evenness. A community shows species diversity, yet a community is described by the major category of growth forms like trees and shrubs. They are called ***dominant species***. There is another castigatory of species called ***keystone species***. A keystone species occupies a critical central role in the community so much so that its activity determines the community structure & dynamics (Paine, 1969). The significance of a keystone species in a community is mostly disproportionate to its dominance status in a community.

Whittaker (1965) described three types of diversity: (a) **α-index diversity** (diversity within one community, (b) **β-index diversity** (diversity between communities). (c) **γ-index diversity** (diversity in the ranges of communities).

Alpha diversity refers to the diversity within a particular area or ecosystem, and is usually expressed by the number of species (i.e., species richness) in that ecosystem. If we examine the change in species diversity between two ecosystems then we are measuring the beta

diversity. Gamma diversity is a measure of the overall diversity for the different ecosystems within a region.

Diversity Indices. Species diversity is calculated by various methods:

Simpson's index

$$D = 1 - \sum_{i-1} S\,(p_1)^2$$

Where D is the index number; S the total number of species sand P the proportion of all individuals in the sample which belongs to species *i*.

Shannon Leaver index

$$H = 1 - \sum \frac{n_1}{n}$$

Where H is the diversity index in bits/individual, n_1 the individual density of one species and n the density of all the species.

Odum's species per thousand individuals

$$Odum's \quad Index = \frac{Total \ number \ of \ species \ encoutered \ in \ the \ sample}{Total \ number \ of \ individuals \ of \ all \ the \ spacies} \times 1000$$

It is an excellect index to determine the level of pollution in the both flowering and standing water bodies (Odum 1960).

Kothe's deficit index

This is based on the principle that in a flowing ecosystem the number of species decreases after they are exposed to some pollutant discharge.

$$Kothe's \quad species \ deficit = \frac{A_1 - A_x}{A_1} \times 100$$

Where A_1 and A_x are the number of species at the unpolluted and polluted sites downstream, respectively.

Other Quantitative Characteristics of a Community

Height of plants: It indicates the vigour of plants growing in an area and gives an idea of the success of a particular species in a particular community.

Weight of plants: Weight is the quantitative expression of the total mass of structural materials, food substances, protoplasm and other materials formed as a result of metabolic processes. Total weight of these substances constitutes the forage value of the herbage. Increase in dry weight is the best measure of growth. Usually above ground parts of the plants are included in weighing, but now root systems are also weighed separately from leaves and stems.

Volume occupied by plants: This refers to the space occupied by the above ground parts of the plants. The word volume refers to the three dimensional space occupied by an individual, as compared to weight which refers to the heaviness property of matter.

Frequency: It can be defined as percentage in which individuals of a particular species occur constantly in a given are or at community.

Tension Zone: It is also called the ***ecotone***. This term is applied to the area which demarcates the two different kinds of communities. This area also has vegetation which includes a large variety of species as compared to the two communities. The tension zone varies in its width. In this region the plants have to face two different types of environments.

2. Synthetic Characteristics

Synthetic Charaters:- The synthetic characteristics are determined after having obtained analytical data (qualitative and quantitative) for each species in a community. The following synthetic features for each species in a community are calculated.

Presence and Constancy: Presence and constancy are calculated by means of quadrat methods, which give us an exact idea of uniformity of distribution of a species in number of sample areas in a particular community. Usually five classes of presence are recognized. These are:-

1. Rare when a species is present in less than 20% of the quadrats.
2. Seldom present when a species occurs in 21-40% of the quadrats.
3. Often present when a species occurs in 41-60% of the quadrats.
4. Mostly present when a species is found in 61-80% of the quadrats.
5. Constantly present when a species is found in 81-100% of the quadrats.

Fidelity: It is defined as a degree with which a particular species is restricted in its distribution to one kind of plant community. It expresses the faithfulness or fidelity of a species to a particular community. Following classes of fidelity are commonly recognized:

(a) **Fidelity I:** It expresses the presence of some rare members of a species that intrude into a community from neighboring communities. They are strangers in a community and are designated as **accidental species**.

(b) **Fidelity II:** It expresses the presence of some indifferent species in a community. Such species show no preference for any particular community. These are designated as **companion species**.

(c) **Fidelity III:** It refers to those species that are present insufficient numbers in several communities but grow in abundance and develop well in a particular type of community. Such species are also designated as **preferential**.

(d) **Fidelity IV:** Such species prefer one community but are found rarely in others. They are called **selective species**.

(e) **Fidelity V:** Such species are restricted only to a particular type of community and are called **exclusive or true**.

Species included under fidelity numbers III-V are also grouped as character faithful species.

Dominance: Usually a community has one or more species that occur in large numbers. Such species are called dominants. Sometimes only one species may be dominant e.g a community may have more trees of *Pinus*. It is called Pine forest or community. Sometimes more than one type of plants are dominant e.g. *Quercus – Rhododendron* forests.

Physiognomy: Physiognomy is a general term that refers to the study of general appearance of a plant community. Physiognomy can be determined by studying the analytical characteristics of a community e.g., dominance, stratification, life forms, cover, competition, density, sociability among species, vigour and vitality. Data obtained from all these characteristics will give a collective idea of the physiognomy or general appearance of the community.

Pattern. In some communities (forests as well grasslands and savannahs) there are present distinct patches of plants at various distances, form of pattern depends upon three main causes that are morphological, sociological and physiogrphic. The morphological causes include several factors such as form of various plant organs, their growth and reproductive capacities especially vegetative propagation. The sociological causes include competition and liking of several species to grow together and flourish well. Physiographic causes include the condition of soil.

Chapter 7: Ecotones and Edge Effect

An area or zone of transition between two or more diverse communities (between forest and grassland or between a soft-bottom and a hard-bottom marine substrate, for example) is known as an **ecotone**.

An **ecotone** is a transition area between two adjacent ecological communities (ecosystems). It may appear on the ground as a gradual blending of the two communities across a broad area, or it may manifest itself as a sharp boundary line.

The word was coined from a combination of *eco*(logy) plus *-tone*, from the Greek *tonos* or tension – in other words, a place where ecologies are in tension.

Boundaries of Communities: Physical Factors behind the creation of Ecotones

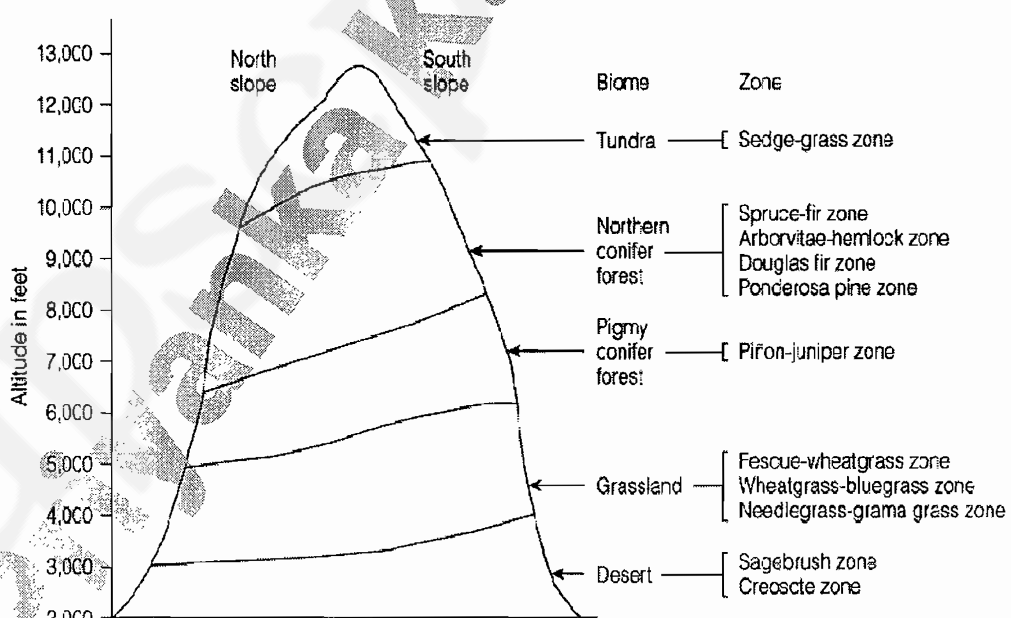
Changes in the physical environment create ecotones.

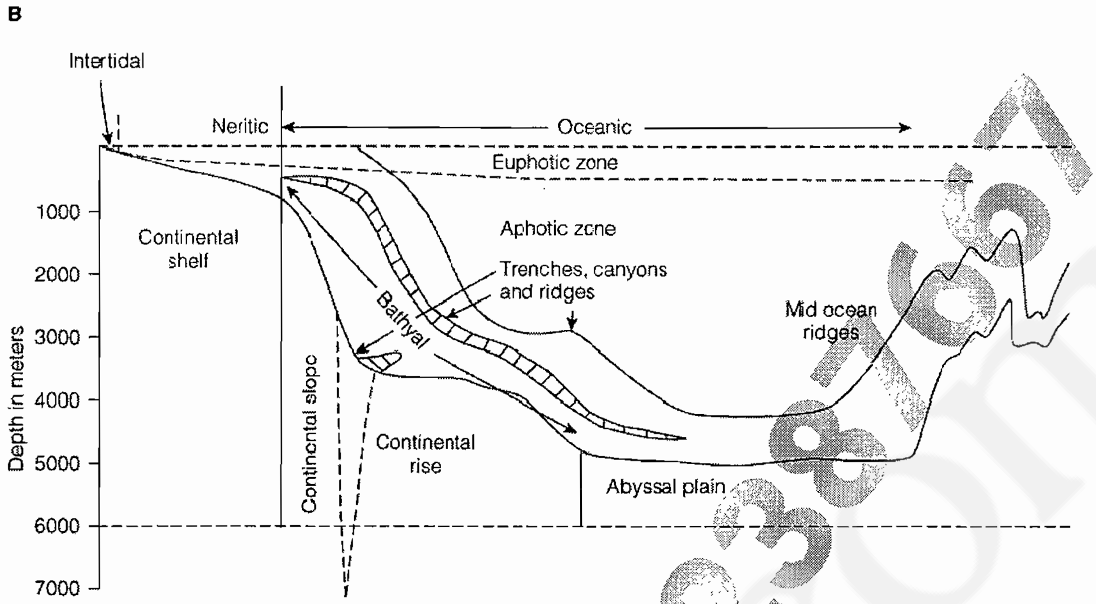
Such changes in the physical environment may produce a sharp boundary, as in the example of a shoreline or the interface between areas of forest and cleared land.

Alternatively, a more gradually blended interface area will be found, where species from each community will be found together as well as unique local species. Mountain ranges often create such ecotones, due to the wide variety of climatic conditions experienced on their slopes. They may also provide a boundary between species due to the obstructive nature of their terrain; Mont Ventoux in France is a good example, marking the boundary between the flora and fauna of northern and southern France. Most wetlands are also ecotones.

Two such examples are shown below.

A





Strayer et al. (2003) classified boundaries into four main classes of boundary traits: 0) *origin and maintenance;* (2) *spatial structure* (such as geometric shape); (3) *function* (such as transmissive or permeable); and *(4) temporal dynamics* (such as age and history of the boundary).

Biotic Aspects of the Ecotones

The ecotonal community commonly contains many of the organisms of each of the overlapping communities in addition to organisms characteristic of and often restricted to ecotones. Often, both the number of species and the population density of some of the species are greater in the ecotone than in the communities flanking it. Frequently, the break between two community types is a sharp demarcation (where a crop field is directly adjacent to a forest, for instance). This narrow zone of habitat transition is frequently termed an edge. The tendency for increased variety and density of species at community junctions is known as the **edge effect**. The edge effect is thus, along the boundary line, an area displaying a greater than usual diversity of species. Species that use edges for purposes of reproduction or survival are frequently termed edge species.

Ecotones are particularly significant for mobile animals, as they can exploit more than one set of habitats within a short distance.

Edge Effect

An **edge effect** is the effect of the juxtaposition of contrasting environments on an ecosystem. This term is commonly used in conjunction with the boundary between natural habitats, especially forests, and disturbed or developed land. Edge effects are especially pronounced in small habitat fragments where they may extend throughout the patch.

Where abrupt changes occur along a landscape gradient, or where two distinctly different habitats or communities border one another, the resulting ecotone or transition zone often supports a community with characteristics different from those of the adjoining communities because many species require, as part of their habitat or life history, two or more adjacent communities that differ greatly in structure. For example, the American robin *(Turdus migratorius)* requires trees for nesting and open, grassy areas for feeding. Because well-developed ecotonal communities may contain organisms characteristic of each of the overlapping

communities plus species living only in the ecotone region, the variety and density of life are greater in the ecotone. This condition is what is meant by *edge effect.*

In a classic pioneer study, Beecher (1942) found that the population density of birds increased as the number of meters of edge per unit area of community increased. From general observation, most people have observed that the density of songbirds is higher on estates, campuses, residential districts, and similar settings, which have mixed habitats (habitat fragmentation) and, consequently, much edge, than on large, nonfragmented tracts of forest or grassland.

Ecotones may also have characteristic species not found in the communities forming the ecotones.

When an edge is created to any natural ecosystem, and the area outside the boundary is a disturbed or unnatural system, the natural ecosystem is seriously affected for some distance in from the edge. In the case of a forest where the adjacent land has been cut, creating an open land/forest boundary, sunlight and wind penetrate to a much greater extent, drying out the interior of the forest close to the edge and encouraging rampant growth of opportunistic species at the edge. Air temperature, vapour pressure deficit, soil moisture, light intensity and levels of photosynthetically active radiation (PAR) all change at edges.

In a 1994 paper *Skole* and *Tucker* estimated that the amount of Amazonian area modified by edge effects exceeded the area that had been cleared. Forest fires are more common close to edges as a consequence of increased desiccation at edges and increased understory growth present due to increased light availability. Increased understory biomass provides fuel that allows pasture fires to spread into the forests. Increased fire frequency since the 1990s are among the edge effects which are slowly transforming Amazonian forests. The amount of forest edge is also orders of magnitude greater now in the United States than when the Europeans first began settling North America. Some species have benefitted from this fact, for example the Brown-headed Cowbird, which is a brood parasite that lays its eggs in the nests of songbirds nesting in forest near the forest boundary. Thus, the more edge in relation to the forest interior, the more cowbirds and the fewer songbirds as a result. Another example of a species benefiting from the proliferation of forest edge is the poison ivy.

In the case of developed lands juxtaposed to wild lands, problems with invasive exotics often result. Species such as Kudzu, Japanese Honeysuckle, and Multiflora Rose have done serious damage to natural ecosystems.

Chapter 8: Ecological Succession

Ecological succession is a fundamental concept in ecology. It is the process by which a natural community moves, through a sequential change in the structure and composition, from a simpler level of organization to a more complex community. It is a long-term cumulative, directional and largely predictable process of natural development of different communities at the same site, in a definite sequence, over a period of time.

Such changes occur either in response to an environmental change or induced by the intrinsic properties of the community itself. Succession continues till a community develops maximum equilibrium to the environment. It is called climax community.

In succession, the characteristic sequence of the developmental stages is termed **sere**.

Succession was first studied by *King* (1685) between open water and peaty terrestrial surface. In the 20th century, a detailed study of community succession has been carried out by *Frederic Clements* and *Arthur Tansley*.

Types of Succession

Ecological Successions have been described using several criteria. Accordingly, there are several types of succession.

Based on Driving Factor

1. **Autogenic Succession.** It is a series of *developmental changes in the structure of vegetation caused by the plants themselves*. Plants of a developmental state produce changes in the habitat initially to favour their growth but the changes go on beyond the optimum to that the habitat becomes unsuitable for them. It paves the way for the growth of another type of plant community.

2. **Allogenic Succession.** Here, the *habitat is changed by action of outside factors* like change in climate, leaching of soil nutrients, increase in salt content of the soil and deposition of salt of sand. The habitat then becomes unsuitable for the colonizers. It favours the growth of a different set of plants.

3. **Induced Succession.** Man has controlled succession in such a way as to obtain a managed steady state in which good amount of organic matter can be harvested. It is called induced succession. In induced succession, like agriculture, a young state is maintained by various types of inputs and protective measures.

Based on Habitat Factor

1. **Primary Succession.** It is the *succession that takes on a primary bare area or an area which was not previously inhabited by plants*. Such an area is biologically sterile and is, therefore, quite hostile for the first lie. Succession is also slow.

2. **Secondary Succession.** It *occurs on a site which has become bare secondarily due to destruction of previous vegetation*. The area is biologically fertile and hence favourable for reappearance of plant life. Succession is quite rapid.

Based on the Predominant Trophic Pattern

1. **Autotrophic Succession.** *The succession involves in appearance and continued dominance of green or autotrophic plants.* Autotrophic succession begins on a medium having little organic matter but quite rich in inorganic substances. There is a net inflow of energy from but side into the communities appearing in succession. Slowly the organic content of the substratum increases.

2. **Heterotrophic Succession.** The succession occurs in an area rich in organic matter, e.g., water bodies receiving sewage, litter, etc. there is a progressive decrease in the energy content. It is dominated by microbes, actinomycetes, fungi, detrivores and other animals. It usually occurs in a microhabitat like dead plant matter, dead animal, dung, etc.

Based on the Sequence of Events

1. **Linear succession**: In this type of succession, the seral stages – that is, the different communities, appear in a linear predictable fashion. Each seral stage is replaced by the next, till a climax community is established.

2. **Deflected Succession.** It is a succession in which the vegetation does not pass through the normal stages of development but either adds or replaces a successional type, e.g., ABB'CDE or AB'CDE instead of the normal ABCDE.

3. **Cyclic Succession** A pattern of succession where the climax community is destroyed again and again and a similar pattern of secondary succession repeats itself every time.

Features of Succession

The four characteristics of succession are as follows:

1. Succession is an orderly sequence of changes in the vegetation of a previously bare area. It is directional and is hence predictable.

2. The rate of change, the pattern of change and the limit of development are determined by the alteration brought about in the physical environment by the existing community. Succession as therefore, a fundamentally biological process.

3. It produces a relatively stable or climax community which is in dynamic equilibrium with the climate. It has the maximum heterogeneity, community relationship and biomass while the net productivity is the minimum.

4. The final or climax community is controlled by climate and not the habitat. Thus succession beginning in water or a rock ends up in similar communities under similar climates. The phenomenon is called convergence.

Changes associated with Community Succession

Habitat conditions	Changes from Hydrism or Xerism to Mesism.

1. Soil.	Maturation of soil and development of soil profile.
2. Non-living organic Matter.	Increases
3. Mineral cycles	Open in beginning. Closed later on.
4. Nutrients exchange amongst organism, detritus and soil.	Poor initially. Later becomes important.
5. Niche specialization	Broad to narrow.
6. Biochemical diversity.	Low to high.
7. Stability.	Increases.
8. Community.	Simple short lived to complex long lived.
9. Species composition.	Changes rapidly in the beginning, more gradually later and then becomes almost stable.
10. Species diversity	Increases in the beginning declines laler on.
11. Size of individuals	Increases
12. Number of autotrophs.	Increases in the beginning but declines later on to becomes stable.
13. Number of heterotrophs	Increases to become stable
14. Total biomass.	Increases
15. Food chains	Become complex and form food webs
16. Net primary productivity.	Increases to stable level in meadow stage, shows linear progress again and later becomes stable.
17. Community respiration.	Increases

18. Net community production.	Decreases
19. P/B ratio	High to low
20. P/R ratio	P>R to P= R
21. Energy flow	Increases from herbivore food chain to decomposer food chain.
22. Stratification and spatial heterogeneity	Poor to well or organized

Why Does Succession Occur?

Every species has a set of environmental conditions under which it will grow and reproduce most optimally. In a given ecosystem, and under that ecosystem's set of environmental conditions, the species that can grow the most efficiently and produce the most viable offspring will become the most abundant organisms. As long as the ecosystem's set of environmental conditions remains constant, those species optimally adapted to those conditions will flourish.

1. **The driving force of succession, the cause of community change, is the impact of established species have upon their own environments.** A consequence of living is the alteration of one's own environment. The original environment may have been optimal for the first species of plant or animal, but the newly altered environment is often optimal for some other species of plant or animal. Under the changed conditions of the environment, the previously dominant species may fail and another species may become ascendant.

2. **Ecological succession may also occur when the conditions of an environment suddenly and drastically change.** A forest fires, wind storms, and human activities like agriculture all greatly alter the conditions of an environment. These massive forces may also destroy species and thus alter the dynamics of the ecological community triggering a scramble for dominance among the species still present.

The Process of Succession

As discussed earlier, succession is a long-term cumulative, directional and largely predictable process of natural development of different communities at the same site in a definite sequence over a period of time. Such changes occur either in response to an environmental change or induced by the intrinsic properties of the community itself. Succession continues till a community develops maximum equilibrium to the environment. It is called **climax community.**

The characteristic sequence of the successional stages includes 8 elementary processes, namely:

1. **Nudation:** It is the creation of bare area. Nudation can occur due to physiographic, climatic or biotic agents.

2. **Migration:** This is the leaving of the parent area by a gemmule and its arrival in a new area. A gemmule consists of reproductive structure like seed, spore or propagule. Propagule is commonly a vegetative structure. It does not help immigration over an appreciable distance except in case of lichen soredia. The gemmules which take part in migration are also called **migrules** or **disseminules.** Migration is influenced by four factors –mobility, agent, distance and topography.

3. **Colonization:** The nature of topography of the bare area also determines the type of the initial vegetation. For example, on bare rock only the spores of some cyanophytes or the soredia of lichens can stick and germinate while in a saline area only te seeds of some halophytes can grow. The first arrivals in a bare area are called **pioneers** or pioneer colonizers. The occupation of a bare area by the pioneers and other invaders is called colonization.

4. **Ecesis:** The establishment of plants in a new place is called ecesis. It consists of three processes- germination, growth and reproduction. Germination depends upon dormancy, and viability of seeds or spores. The most critical stage of life cycle is the seedling stage. It may face prdation from animals and adverse environment in the form of lack or defieincy of water, light, temperature and soil depth. Maximum mortality occurs in the seedling stage. If the seedling gets established, it grows in size. During its growth the plants may have to pass thorugh adverse conditions and die or remain vegetative. Reproduction is the final stage of ecesis.

5. **Aggregation:** It is the increase in number of the colonizing individuals. In the beginning the pioneers are few in number and grow far from one another. They produce a large number of disseminules which spread in the open areas and increase the number of pioneers. If invasion continues and the invaders are also able to multiple, the phenomenon is called **mixed aggregation.**

6. **Competition:** It may be intraspecific (among individuals of the same species) or interspecific (among individuas of the different species). Competition occurs when the availability of a necessity becomes inadequate to meet the optimum requirement of all the individuals growing in that area. The competition can be for space, light and heat among the epiterannean parts and for space, water and minerals among the subterranean parts of different individuals. intraspecific competition is generally more acute because of the similar requirements and similar adaptations of the individuals of the same species.

7. **Reaction:** It is the change brought about by colonizers in the habitats. The first reaction is localized. It consists of such changes as bindings of soil particles, assisting in weathering or building soil at the bottom of a water reservoir. Later on, besides the soil the climate of the climate of the habitat is also changed. Vegetation has retarding effect on wind. It protects the ground from the direct action of ration fall and insulation. Death of roots produces channels in the soil for quick absorption of rain water. Humus produced by the death of older or weak plants increases water retention, aeration and nutrition of the soil. The reaction of the early colonizers is such as to make the habitat less favourable to themselves and more favourable to invaders. The reaction of the latter invites new invaders and so on.

8. **Stabilization:** Continuous competition invasion and reaction give rise to continuous changes in the environment and structure of vegetation. After a long interval some individuals arise which are in complete harmony with the climate of the area. This is termed as stabilization.

The sequence of the above stages is termed a **sere.** The traditional view, most notably expressed by **Frederic Clements**, holds that there is an orderly, predictable sequence of *seres*, or plant communities resulting from a single stage of succession, culminating in a stable climax. The presence of one set of colonizers changes the environment in such as way that the next set of colonizers can join or replace it.

Primary Sere → **Secondary Sere→** **.... →** **nth Sere** **→** **Climax**

Because resource availability changes over the course of succession, different species compete better at different stages. Early stages are typically characterized by *r*-selected species that are good colonizers because of their high fecundity and excellent dispersal mechanisms. Many of these may be described as 'fugitive' or 'weedy' species that do not compete well in established communities, but maintain themselves by constantly colonizing newly disturbed areas before better competitors can become established in the same places.

In Figure 1, different seral stages are shown in primary succession starting in a fresh water body.

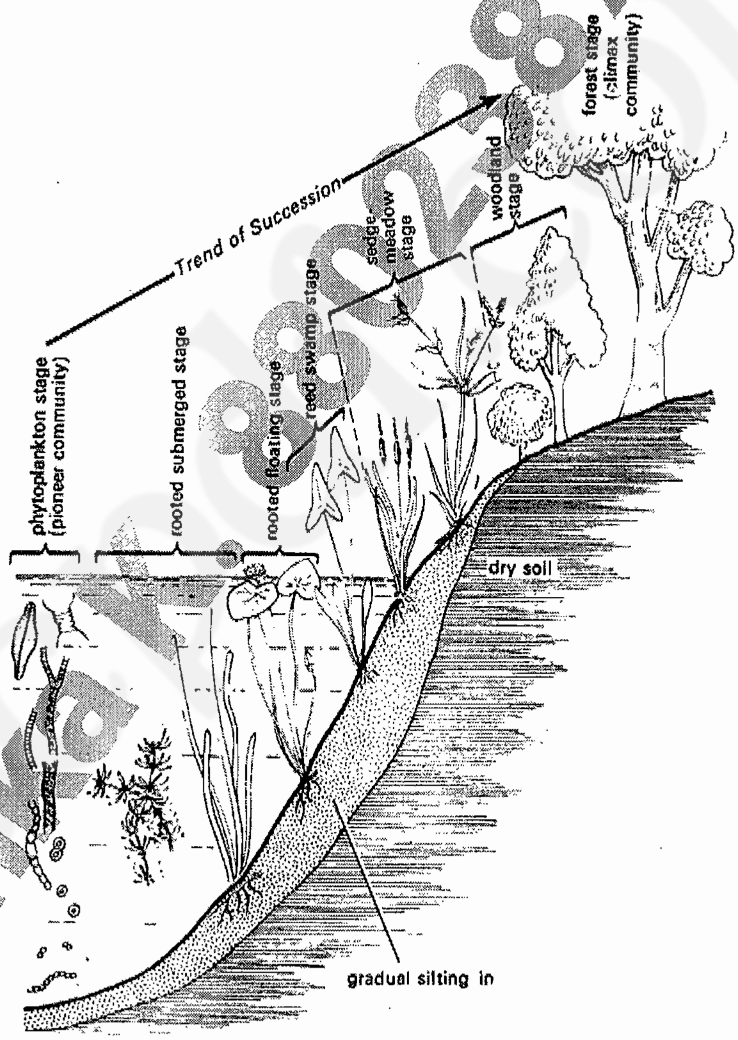


Figure 1 (Reproduced from ECOLOGY & ENVIRONMENT, Dr. P.D. Sharma)

Diagram showing different plant communities appearing at different stages of a hydrosere originating in a pond. Note the gradual decrease in water level and successive development of the soil in area to give finally a terrestrial habitat for forest climax community.

Figure 1: Different seral stages in primary succession starting in a fresh water body

Climax Community

In nature, every system moves towards greater stability. The climax community represents a stable end product of the successional sequence. We can say that a community develops over time to a **climax community**. The community may not reach climax, instead stopping at a **subclimax community**. The community may be diverted to

a **disclimax community** by an **arresting factor**. The arresting factor could be, for example, a feral animal or feral weed.

At the climax stage, environmental conditions are such that the same species can continue to maintain themselves. Climax communities will remain in place until either the climate changes, a much better competitor arrives, or the community is catastrophically disrupted.

To explain the nature of the climax communities, different theories have been proposed from time to time. The important climax theories are as follows.

1. *Monoclimax theory* (Clements): All vegetation within a region will converge to the same vegetation type, which is regulated by homeostasis.

2. *Polyclimax theory* (Tansley): There are a number of types of climax within a region, each of which reflects a different soil type, local climate, etc.

3. *Climax-Pattern theory* (Whittaker): Succession will result in a continuum of climax types, varying along environmental gradients.

4. *Nonequilibrium hypotheses*: Climax rarely, if ever, occurs; change is continual. History and random events are important. Even if equilibrium is theoretically possible, disturbance is too frequent to allow it.

5. *Informational Climax theory* (Odum): Climax is the state where there is the highest level of biomass and energy storage.

6. *Shifting mosaic steady state*: Although the vast majority of sites in a landscape are changing (recovering from disturbance), the landscape may be in a steady state. This is because there is, through time, a reasonably constant portion of the landscape in each successional stage. A shifting mosaic steady state is a special case of a *Dynamic Equilibrium*.

Later developments in the field of ecology led to the decline of climax theory. The recent theories state that the timelines required for the development of climax vegetation are unrealistically long, and most vegetation can better be explained by factors prevailing stably in a region.

Some Well Known Examples

1. The Glacier Bay, Alaska, area in the USA was ice covered until recently. It now presents an example of the development of a plant community on a bare inorganic substrate, where all the stages of a primary succession can be observed.

2. In the Post Glacial periods, the *Sphagnum* moss played an important role in water body to land succession in many areas of northern hemisphere. Much of the coniferous forests in northern Europe are results of primary succession in fresh water bodies created after the post glaciations melting of ice.

3. Indiana Dunes National Lakeshore, in the USA was studied in 1899 by Henry Cowles. The habitat contains beaches, sand dunes, bogs, marshes, swamps, prairies, rivers, oak savannas, and woodland forests supporting more than 350 species of birds, 200 other animal species, 1418 vascular plant species etc. This location is unique as contains both arctic and boreal

plants alongside desert plants. This is considered a classic example of mosaic type of climax community.

Chapter 9: Biodiversity & related issues

Introduction to biodiversity

The term biodiversity is a shortened form of biological diversity. The term biological diversity was coined by Thomas Lovejoy in 1980.

Biological diversity or biodiversity is the totality of genes, species, and ecosystems of a region. It has three components.

1. Genetic diversity: The diversity of genes within a species. There is a genetic variability among the populations and the individuals of the same species
2. Species diversity: The diversity among species
3. Ecosystem diversity: The diversity of the ecological complexes of which the species are part.

The biodiversity is mostly expressed in terms of species diversity. So far, about 1.75 million species have been identified and described. A broad break up of this species diversity is shown in Figure 1. Scientists estimate that there are actually about 13 million species.

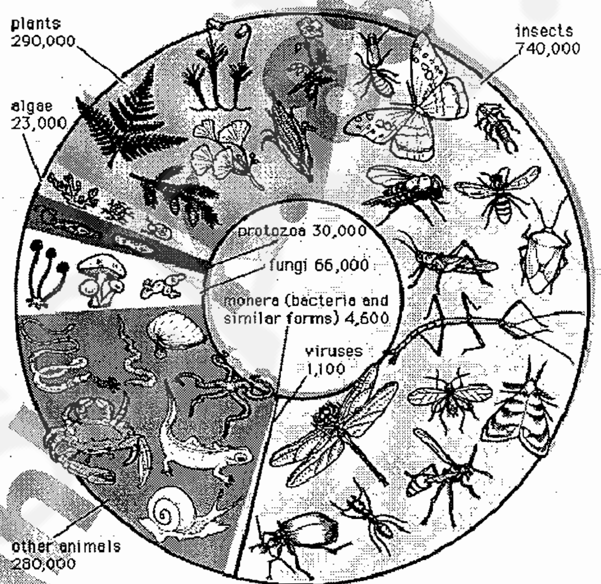


Figure 7: A broad break-up of species diversity in the biosphere

The value of biodiversity

Biological diversity plays a fundamental role in maintain the ecological balance on the earth. It also provides varieties of products of human interest. A brief list of product and service categories in which biodiversity contributes is given below.

1. Provision of food, fuel and fibre

2. Provision of shelter and building materials
3. Purification of air and water
4. Detoxification and decomposition of wastes
5. Stabilization and moderation of the Earth's climate
6. Moderation of floods, droughts, temperature extremes and the forces of wind
7. Generation and renewal of soil fertility, including nutrient cycling
8. Pollination of plants, including many crops
9. Control of pests and diseases
10. Maintenance of genetic resources as key inputs to crop varieties and livestock breeds, medicines, and other products
11. Cultural and aesthetic benefits
12. Ability to adapt to environmental changes

Biodiversity under threat

Because of variety of factors – mostly directly or indirectly caused by humans – biodiversity today faces a threat of unprecedented scales.

Based on the current trends, an estimated 36,000 plant and 7,800 animal species face extinction globally. Most of the ecosystems in the world are at different levels of degradation (Perkin, 2010).

Factors causing threat to biodiversity

The main reasons behind depletion of biodiversity are as follows.

1. Destruction of natural habitats of species for making land available for human settlements, urban centres, industries and mines, agriculture etc.
2. Ecosystem degradation due to various types of pollution
3. Overharvesting of biological resources and targeted elimination in some cases
4. Introduction of exotic and invasive species in various ecosystems
5. Disturbances in ecosystem dynamics due to climate change

If these factors are not checked immediately and rigidly, the sustenance of most of the ecosystems including our food production systems can be very seriously disrupted.

Biodiversity Hot Spots

A **biodiversity hotspot** is a biogeographic region that is both a significant reservoir of biodiversity and is threatened with destruction. Most of these hotspots are located in the tropics.

A biodiversity hotspot is a biogeographic region with a significant reservoir of biodiversity that is under threat from humans.

The concept of biodiversity hotspots was given by **Norman Myers**. To qualify as a biodiversity hotspot, a region must meet two strict criteria: it must contain at least 0.5% or 1,500 species of vascular plants as endemics, and it has to have lost at least 70% of its primary vegetation.

The Biodiversity hotspots are identified by Conservation International (CI). Currently there are 34 biodiversity hot spots in the world. These biodiversity hotspots have 2.48 percent of the land surface, yet support nearly 70 percent of the world's plant, bird, mammal, reptile, and amphibian species.

The 34 Biodiversity hotspots by region are given below. ***Four hot-spots fall within the Indian territory***.

North and Central America

1. California floristic province
2. Caribbean Islands
3. Madrean pine-oak woodlands
4. Mesoamerica

South America

1. Atlantic Forest
2. Cerrado
3. Chilean Winter Rainfall-Valdivian Forests
4. Tumbes-Chocó-Magdalena
5. Tropical Andes

Europe and Central Asia

1. Caucasus
2. Irano-Anatolian
3. Mediterranean Basin
4. Mountains of Central Asia

Africa

1. Cape Floristic Region
2. Coastal forests of eastern Africa
3. Eastern Afromontane
4. Guinean Forests of West Africa
5. Horn of Africa
6. Madagascar and the Indian Ocean Islands
7. Maputaland-Pondoland-Albany

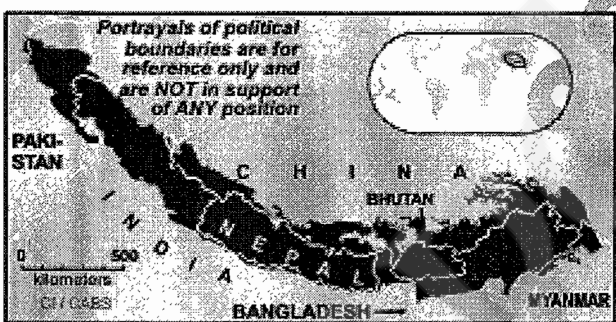
8. Succulent Karoo

Asia-Pacific

1. East Melanesian Islands
2. **Himalaya** (A large part falls within Indian Territory)
3. **Indo-Burma** (A large part falls within Indian Territory)
4. Japan
5. Mountains of Southwest China
6. New Caledonia
7. New Zealand
8. Philippines
9. Polynesia-Micronesia
10. Southwest Australia
11. **Sundaland** (A small part falls within Indian Territory)
12. Wallacea
13. **Western Ghats and Sri Lanka** (A large part falls within Indian Territory)

The 4 Indian Hotspots

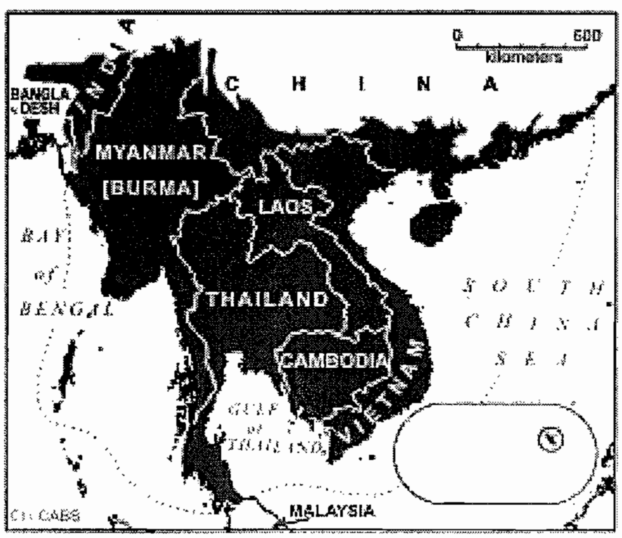
The Himalayan Hot Spot



The Himalaya Hotspot is home to the world's highest mountains, including Mt. Everest. The mountains rise abruptly, resulting in a diversity of ecosystems that range from alluvial grasslands and subtropical broadleaf forests to alpine meadows above the tree line. Vascular plants have even been recorded at more than 6,000 meters. The hotspot is home to important populations of numerous large birds and mammals, including vultures, tigers, elephants, rhinos and wild water buffalo.

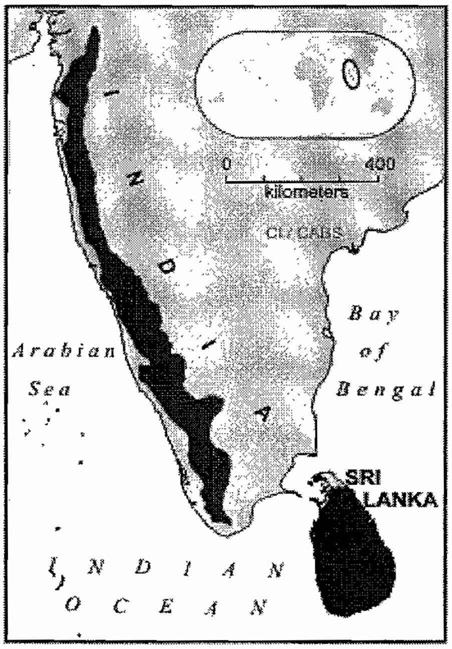
Indo-Burma Hotspot

It encompasses more than 2 million km² of tropical Asia. The Indo-Burma is one of the richest yet very fragile hotspots. Six large mammal species have been discovered lately. This hotspot also holds remarkable endemism in freshwater turtle species, most of which are threatened with extinction, due to over-harvesting and extensive habitat loss. Bird life in Indo-Burma is also incredibly diverse, holding almost 1,300 different bird species, including the threatened white-eared night-heron, the grey-



crowned crocias, and the orange-necked partridge.

Western Ghats and Sri Lanka

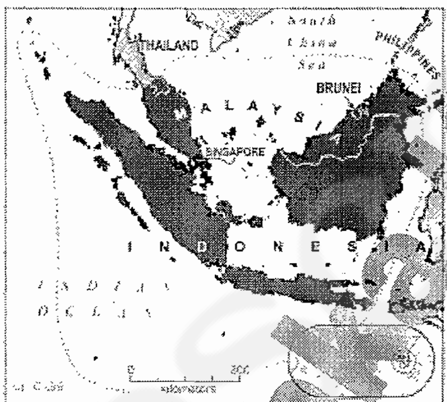


This hotspot has a rich endemic assemblage of plants, reptiles, and amphibians. Sir Lanka alone may be home to as many as 140 endemic species of amphibians. The region also houses important populations of Asian elephants, Indian tigers, and the Endangered lion-tailed macaque. Freshwater fish endemism is extremely high as well, with over 140 native species.

Sundaland Hotspot

The Sundaland hotspot covers the western half of the Indo-Malayan archipelago, an arc of some 17,000 equatorial islands, and is dominated by two of the largest islands in the world: Borneo (725,000 km²) and Sumatra (427,300 km²).

Politically, Sundaland covers a small portion of southern Thailand (provinces of Pattani, Yala, and Narathiwat); nearly all of Malaysia (nearly all of Peninsular Malaysia and the East Malaysian states of Sarawak and Sabah in northern Borneo); Singapore at the tip of the Malay Peninsula; all of Brunei Darussalam; and all of the western half of the megadiversity country of Indonesia, including Kalimantan (the Indonesian portion of Borneo, Sumatra, Java, and Bali). **The Nicobar Islands of India are also included**.



Sundaland is one of the biologically richest hotspots on Earth, holding about 25,000 species of vascular plants, 15,000 (60 percent) of which are found nowhere else. One plant family, the Scyphostegiaceae, is confined to the hotspot and is represented by a single tree species, *Scyphostegia borneensis* from Borneo.

Of the approximately 770 bird species that regularly occur in Sundaland, nearly 150 are endemic; around 40 of these endemic species are threatened.

Of Sundaland's more than 380 mammal species, over 170 are endemic to the hotspot. In addition, 17 of 136 genera are endemic.

Convention on Biodiversity (CBD)

The Convention on Biological Diversity or the CBD is one of the key agreements adopted at the 1992 Earth Summit in Rio de Janeiro. The CBD makes commitments for maintaining the world's biodiversity.

The CBD is essentially a multilateral international agreement, of which India too is a party. It has now a near universal membership with 189 countries as its partners.

The Convention has three main goals:

1. The conservation of biodiversity,
2. Sustainable use of the components of biodiversity, and
3. Sharing the benefits arising from the commercial and other utilization of genetic resources in a fair and equitable way.

The CBD deals with the following main issues.

1. Measures and incentives for the conservation and sustainable use of biological diversity.
2. Regulated access to genetic resources.
3. Access to and transfer of technology, including biotechnology.
4. Technical and scientific cooperation.
5. Impact assessment.
6. Education and public awareness.
7. Provision of financial resources.
8. National reporting on efforts to implement treaty commitments.

The Convention's ultimate authority is the Conference of the Parties (COP), consisting of all governments (and regional economic integration organizations) that have ratified the treaty. The COP can make amendments to the Convention. This body also reviews progress under the Convention, identifies new priorities, and sets work plans for members.

Indian action towards conserving the biological diversity

India is one of the 19-mega biodiversity countries of the world. With only 2.4% of the land area, India already accounts for 7-8% of the recorded species of the world.

India ranks among the top ten species-rich nations and shows high endemism. India has four global biodiversity hot spots (Eastern Himalaya, Indo-Burma, Western Ghats and Sri Lanka, and Sundaland).

India has so far documented over 91,200 species of animals and 45,500 species of plants in its ten bio-geographic regions. Besides, it is recognized as one of the eight Vavilovian centres of origin and diversity of crop plants, having more than 300 wild ancestors and close relatives of cultivated plants, which are still evolving under natural conditions. India is also a vast repository of Traditional Knowledge (TK) associated with biological resources.

The varied edaphic, climatic and topographic conditions and years of geological stability have resulted in a wide range of ecosystems and habitats such as forests, grasslands, wetlands, deserts, and coastal and marine ecosystem.

India is also a Party to the CBD. India ratified the International Convention of Biological Diversity (CBD) on 18th February, 1994 and became party to the Convention in May 1994.

Even before this convention, India has actively been involved in both in situ and ex situ conservation efforts towards biodiversity.

Biosphere Reserves in India

As a significant measure towards in situ conservation of biological diversity India has an extensive protected area network and the Biosphere Reserves. As of now, The Indian government has established **18 Biosphere Reserves** in India. These are:

Name	State
1. **Nilgiri Biosphere Reserve**	Tamil Nadu, Kerala and Karnataka
2. **Nanda Devi**	Uttarakhand
3. **Nokrek**	Meghalaya
4. **Gulf of Mannar**	Tamil Nadu
5. **Sunderbans**	West Bengal
6. **Manas**	Assam
7. **Great Nicobar Biosphere Reserve**	Andaman and Nicobar Islands
8. **Simlipal**	Orissa
9. **Dibru-Saikhowa**	Assam
10. **Dehong Deband**	Arunachal Pradesh
11. **Pachmarhi Biosphere Reserve**	Madhya Pradesh
12. **Kanchanjunga**	Sikkim
13. **Agasthyamalai Biosphere Reserve**	Kerala
14. **Achanakamar-Amarkantak**	Madhya Pradesh,Chattisgarh
15. **Rann of Kuchch**	Gujarat
16. **Cold Desert**	Himachal Pradesh
17. **Seshachalam Hills**	Andhra Pradesh
18. **Panna**	Madhya Pradesh

Legal and Policy Initiatives

Prior to CBD, India has already been having legal provisions dealing with aspects relating to biodiversity. They are:

1. Indian Forest Act, 1927
2. Wildlife (Protection) Act, 1972
3. Forest (Conservation) Act, 1980

India Forest Act and Forest (Conservation) Act deal with management of forests and conservation of forestland respectively. Wildlife (Protection) Act is for the protection of wild animals, birds and plants, and basically aims at protecting, propagating or developing wildlife or its environs through national parks, sanctuaries etc. In addition, the Act has a provision to prohibit picking and uprooting etc. of specified plants.

Certain recent initiatives towards maintenance of biodiversity have been as follows.

1. Biological Diversity Act, 2002 was passed and notified. The act primarily addresses access to genetic resources and associated knowledge by foreign individuals, institutions or companies, to ensure equitable sharing of benefits arising out of the use of these resources and knowledge to the country and the people.

2. A National Biodiversity Authority set up at Chennai on 1st October,2003 as per the provision of the Biological Diversity Act, 2002, is mandated to facilitate implementation of the Act. In compliance with the provisions of the Act, eighteen states have formed State Biodiversity Boards and other states are in process of establishing State Boards.

3. Subsequent to the approval of the National Environment Policy (NEP) by the Cabinet in 2006, a draft National Biodiversity Action Plan (NBAP) in consonance with the NEP was finalised.

4. India chaired the Group of Like Minded Megadiverse Countries (LMMCs) for a period of two years from March, 2004 to March, 2006. India played an important role in the development of a common position of LMMCs for the negotiations for developing an international regime on access and benefit sharing.

5. Recently, the National Biodiversity Action Plan was approved in November 2008 to augment natural resource base and its sustainable utilisation. The Plan draws from the principles of National Environment Policy, incorporates suggestions made by a consultative committee and proposes to design actions based on the assessment of current and future needs of conservation and sustainable utilization.

Biodiversity Act, 2002

After the Convention on Biological Diversity (CBD) was adopted by the United Nations, in June1992, the contracting countries (India being one of them) were required to integrate consideration of conservation and sustainable use of biological diversity into relevant legal procedures, programmes and policies.

The Biological Diversity Act (BDA) was formulated after India became signatory to the CBD. The Act was passed by the Parliament in December 2002 .

The objectives of the Act are 'to provide for conservation of biological diversity, sustainable use of its components and equitable sharing of the benefits arising out of the use of biological resources and for matters connected therewith or incidental thereto'.

Salient provisions

Some of the salient provisions made in the BDA for regulation of access to biological diversity, its conservation and sustainable use are:

1. Conservation and sustainable use of biological diversity.

2. Conservation and development of areas important from the standpoint of biological diversity by declaring them as biological diversity heritage sites.

3. Protection and rehabilitation of threatened species.

4. To respect and protect knowledge of local communities related to biodiversity.

5. Regulation of access to biological resources of the country with the purpose of securing equitable share in benefits arising out of the use of biological resources, and associated knowledge relating to biological resources.

6. To secure sharing of benefits with local people as conservers of biological resources and holders of knowledge and information relating to the use of biological resources.

7. Involvement of institutions of self-government in the broad scheme of the implementation of the Act through constitution of committees.

Proposed institutional mechanisms

For the effective implementation of the BDA, the Central Government would undertake activities to develop national strategies, plans and programs for conservation and sustainable use of biological resources.

It is proposed to have National Biodiversity Authority (NBA), State Biodiversity Boards (SBB) and Biodiversity Management Committees (BMC) for effective implementation of the Act.

The NBA will deal with matters relating to requests for access by foreign individuals, institutions or companies, and those relating to transfer of results of research to any foreigner. Imposition of terms and conditions to secure fair and equitable sharing of benefits arising out of utilization of biological resources and approvals for seeking any form of Intellectual Property Rights (IPR) in or outside India for an invention based on research or information pertaining to a biological resource or knowledge associated there to obtained from India, would also be dealt with by the NBA.

SBB would be constituted for every state in India to deal with matters relating to access by Indians for commercial purposes and restrict any activity which violates the objectives of conservation, sustainable use and equitable sharing of benefits.

Institutions of self-government in their respective areas would constitute a BMC for conservation, sustainable use, documentation of biodiversity and chronicling of knowledge relating to biodiversity. BMC shall be consulted by the NBA and SBB on matters related to use of biological resources and associated knowledge within their jurisdiction.

It is also proposed to set-up 'Biodiversity Funds' at central, state and local levels. The monetary benefits, fees and royalties received as a result of approvals by NBA will be deposited in the 'National Biodiversity Fund'. The Fund will be used for conservation and development of areas from where resources have been accessed, including management and conservation of heritage sites wherever applicable.

Recent steps taken by India in the direction of Biodiversity Conservation

1. **India has recently ratified the Nagoya Protocol** and formalised our commitment to it. The Nagoya Protocol on access and benefit sharing has been negotiated under the aegis of CBD, and adopted by the Tenth Conference of Parties (COP-10) held in Nagoya, Japan in October 2010. The Nagoya Protocol would contribute to fair and equitable sharing of benefits accruing from utilization of genetic resources would act as incentive to biodiversity-rich countries and their local communities to conserve and sustainably use their biodiversity.
2. India has, for the first time, **hosted the 11 Conference of Parties (CoP-11)** to the Convention on Biological Diversity. This is also the first such Conference since the launch of the United Nations Decade of Biodiversity in 2011.
3. At the CoP-11, India has launched the **Hyderabad Pledge** and announced that our Government will **earmark a sum of USS 50 million** during India's presidency of the Conference of Parties to the Convention on Biological Diversity **to strengthen the institutional mechanism for biodiversity conservation in India.** India will use these funds to enhance the technical and human capabilities of our national and state-level mechanisms to attain the Convention on Biological Diversity objectives.
4. India has **also earmarked funds to promote similar capacity building in developing countries**
5. In recent years there has been concern that this public knowledge may become restricted in its use because of the application of the modern intellectual property system. India has tried a unique approach to protection of traditional knowledge by **establishing a Traditional Knowledge Digital Library.** This database has 34 million pages of information in five international languages in formats easily accessible by patent examiners. This Library promotes the objectives of the Nagoya Protocol on the issue of protection of codified traditional knowledge systems such as the celebrated Ayurveda. India decided to build this knowledge database because of the patent on the use of neem extract in Europe and another on the use of turmeric as a healing agent. Since then, because of this database, over 1000 cases of biopiracy have been identified and over 105 claims withdrawn or cancelled by patent offices.

Many development schemes have been realigned to provide biodiversity-related benefits. This is vital to protect habitats, including our water bodies, which are beyond our protected areas. The Mahatma Gandhi National Rural Employment Guarantee Scheme, for example, aims to create legally mandated green jobs for every rural household in our country.

Chapter 10: Green House Effect, Global Warming and Kyoto Protocol

Introduction to global warming, the Green House Effect and climate change

Global warming is the rise in temperature of the earth's atmosphere and oceans over time. The global warming studies tell us that the global temperature has continuously been rising since the late 19th century largely due to human causes.

More scientifically, ***global warming*** means accelerated warming of the Earth's surface due to anthropogenic (human activity-related) releases of greenhouse gases due to industrial activity and deforestation.

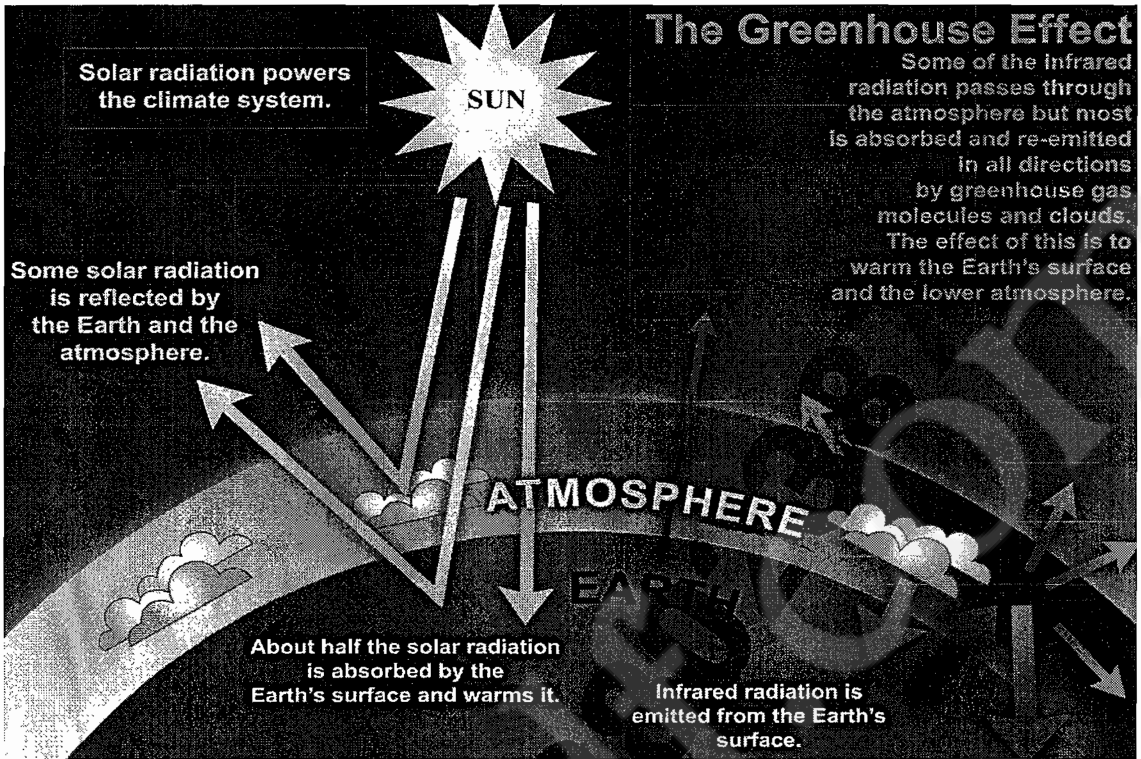
The Fifth Assessment Report (AR-5, 2014) of the UN's Intergovernmental Panel on Climate Change (IPCC) estimated that the global temperature has risen by a magnitude between 1.4°C and 5.8°C between the years 1900 and 2012. Of the 10 warmest years on record, 9 occurred between after the year 2000. The year **2014 was acknowledged as the Earth's warmest year on record** since record keeping began in 1880.

Table: Ten warmest years on record

Rank	Year
1	2014, 2015
2, 3 (tie)	2010, 2005
4	1998
5, 6 (tie)	2013, 2003
7	2002
8	2006
9, 10 (tie)	2009, 2007

Climate change in IPCC usage refers to any change in climate over time, whether due to natural variability or as a result of human activity. This usage differs from that in the UN Framework Convention on Climate Change (UNFCCC), where climate change refers to a change of climate that is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and that is in addition to natural climate variability observed over comparable time periods.

Figure: The Green House Effect



Greenhouse Effect is term for the role the atmosphere plays in helping to warm the Earth's surface. The atmosphere is largely transparent to incoming solar radiation, because it is largely comprised of rays of shorter wave lengths. Much of this incoming radiation is absorbed by the Earth's surface. The hot surface of the earth then re-emits heat energy at long-wave infrared rays. While some of the infrared radiation passes through the atmosphere, a large part of it is absorbed and redistributed back by gases such as carbon dioxide, methane, nitrous oxide, halocarbons, water vapour and ozone in the atmosphere. This heating effect is called the green house effect and it causes global warming.

The greenhouse effect has two types:

- The **natural greenhouse effect**, which refers to the greenhouse effect which occurs naturally on earth and it is essential to maintain normal global temperature patterns. Without it, temperatures would drop by approximately 30°C, the oceans would freeze and life as we know it would be impossible.

- The **enhanced (anthropogenic) greenhouse effect**, which results from human activities. It is this green house effect that is a cause of serious concern for the global environment.

The gases present in the earth's atmosphere which absorb and redistribute the infrared heat radiations are called the ***green house gases.***

The important green house gases include:

1. Water Vapour

2. Carbon dioxide (CO_2)

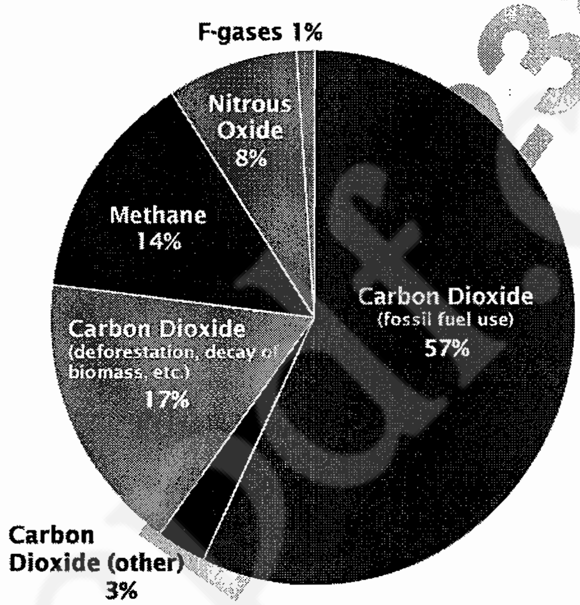
1. Methane (CH_4)
2. Nitrous oxide (N_2O)
3. Fluorinated gases (F-gases)

    a. HFCs

    b. PFCs

    c. SF_6

The respective contributions of different green house gases are as follows.

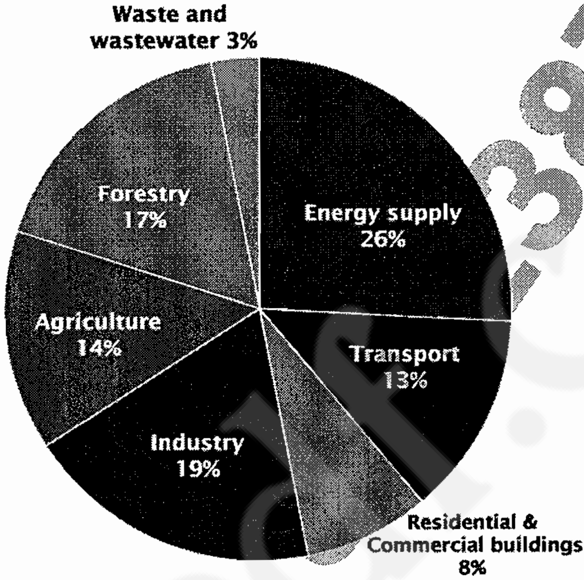


Human activities leading to the accelerated green house effect

In the recent centuries, a number of human activities have led to a sharp increase in the concentrations of several greenhouse gases. These human activities include:

- Heavy industrialization, power generation and urbanization & transportation based on burning of fossil fuel. Since CO_2 is emitted from the burning of fossil fuels, so most electricity production and most industrial activity contribute to global warming.
- Urban automobiles and various industries which release CO_2, NO_X and SO_X. Since gasoline, kerosene, and diesel are fossil fuels, they too contribute, which means that the entire transport sector is implicated.
- Burning of fossil fuels for domestic purposes. Both CO_2 and Methane are emitted from fossil fuel burning for domestic purposes.
- Deforestation leading to higher carbon dioxide concentrations because it depletes away the carbon sink.

- Cattle rearing and paddy rice farming, land use and wetland changes, pipeline losses, and landfill emissions leading to higher methane concentrations.
- Use of CFCs in refrigeration systems. The use of CFCs and other halons in fire suppression systems and various manufacturing processes.
- Fossil burning and fertilizers, which are sources of Nitrous oxide
- The burning of forests, which contributes significantly to CO_2 emissions



Latest emission figures

Recently a group of climate scientists collaborating at the **Global Carbon Project** released a Report on Global Emissions of CO_2. The Report reveals that CO_2 emissions rose 5.9 per cent in 2010 – which means addition of a half-billion extra tons of carbon pumped into the air. It is the largest absolute jump in any year since the Industrial Revolution, and the largest percentage increase since 2003. Remarkably, there was a 1.4 per cent drop in emissions in 2009 (though this was not due to emission reduction efforts but more because of economic recession).

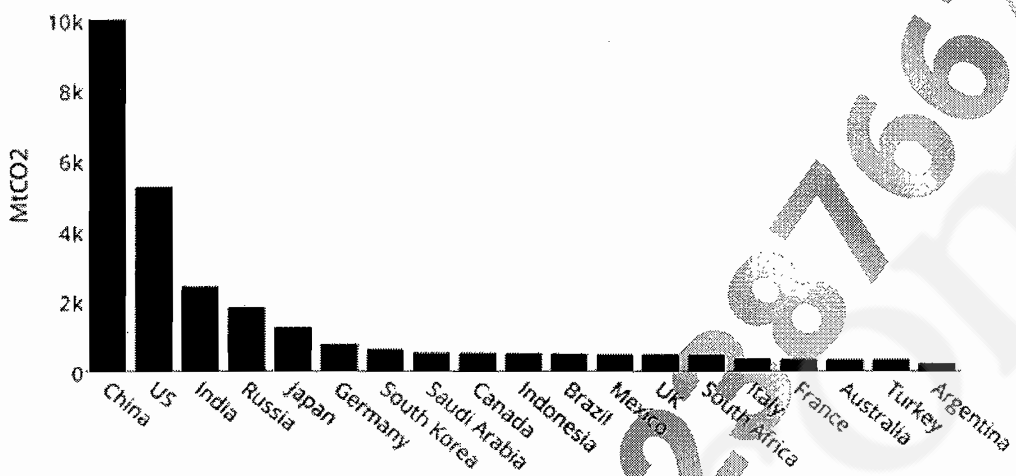
The main reasons

The main reasons for such a spike in CO_2 emission are as follows.

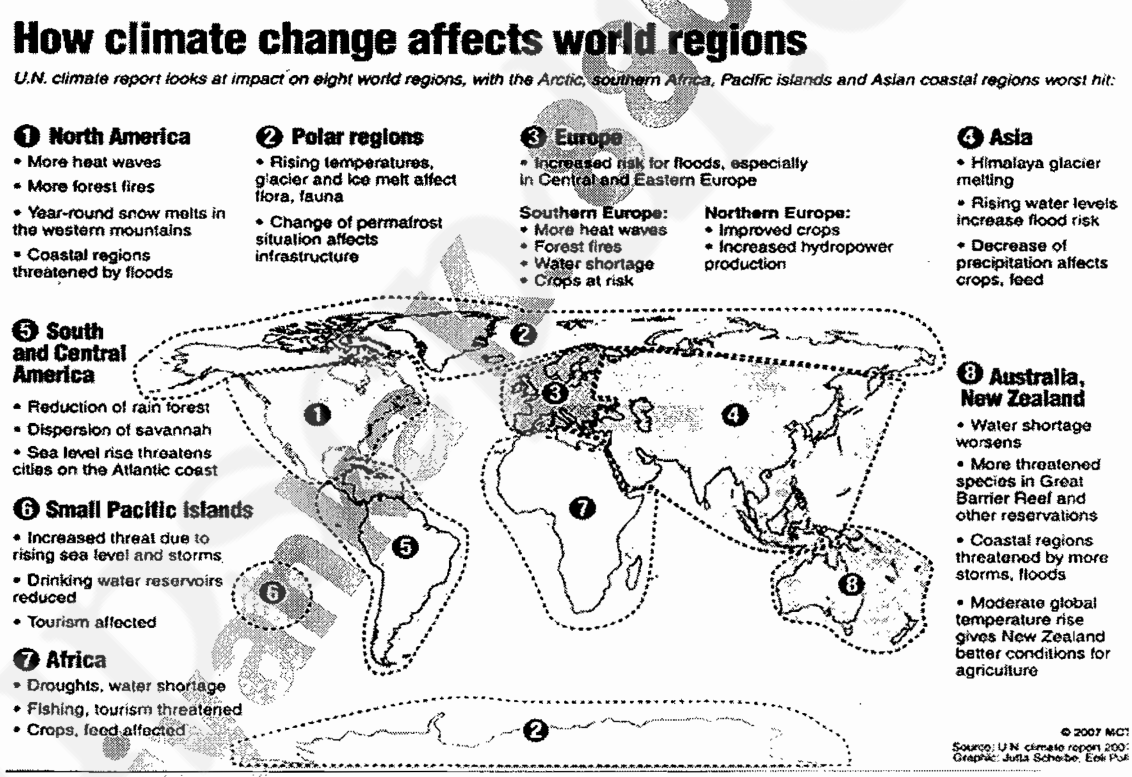
- The combustion of coal rose sharply. It represented more than half of the growth in emissions.
- The fast growth of China has also been an important factor. **China is the single largest Green House Gas emitter in the world**. Here, emissions grew 10.4 per cent in 2010, with that country injecting 2.2 billion tons of carbon into the atmosphere. In the United States, emissions dropped by a remarkable 7 per cent in the recession year of 2009, but rose by just over 4 per cent last year.
- Use of older manufacturing technology in developing countries has also contributed significantly. In 2010, the combustion of fossil fuels and the production of cement sent

more than 9 billion tons of carbon into the atmosphere, with 57 per cent of that coming from developing countries.

The biggest emitters (as in 2013)



Effects of climate change



IPCC Assessment Report 5

In 2014, the UN's Intergovernmental Panel on Climate Change (IPCC) released its Fifth Assessment Report (AR-5). The Fourth Assessment Report was released in 2007.

This report has concluded that there is more certainty than ever before that earth is warming under human influence. The report goes on to warn that only substantial and sustained reduction of greenhouse gas emissions will limit the disaster of climate change.

In this latest report, the IPCC has raised the likelihood of human activities causing global warming from "very likely" in its 2007 report to "extremely likely" — moving from being 90% sure to 95% sure.

IPCC scientists say that global warming has resulted in an average sea level rise of 19cm since 1901 and an increase in surface temperature by 0.85 degrees Celsius between 1880 and 2012.

The report gives temperature rise projections for the end of this century to 0.3-4.8 degrees.

The report puts the blame for warming on the atmospheric concentration of carbon dioxide (CO_2) more than methane, hydrofluorocarbons (HFC) and black carbon — which are present in smaller quantities in the air and exist for much shorter periods. This finding is likely to help India and other developing countries relying heavily on agriculture and cattle rearing. These counties have increasingly come under pressure from the developed nation for the methane emissions from cattle gut as well as from practices of submerged paddy farming. Developed countries have been pressuring emerging nations to cut emissions of these short-lived gases while the latter have been demanding the West undertake more meaningful cuts in CO_2 levels.

The main findings of the Report

4. Global warming is unequivocal.
5. Many observed changes since 1950s have been unprecedented over millennia and the period between 1983 and 2012 is likely the warmest in 1,400 years.
6. Global temperature rise may exceed 1.5°C by the year 2100.
7. It is 'extremely likely' that human influence has been dominant cause of warming since 1950.
8. Oceans will continue to warm, affecting circulation.
9. There has been 0.19m rise in sea level during 1901–2010. By 2100, rise is likely to be 0.26-0.98m.
10. There is an alarming retreat of Arctic sea ice, with the north snow cover down 11.7% per decade.
11. Frequency & duration of heat waves is likely to increase.
12. For India, Monsoon winds are likely to weaken, but rain will intensify. Monsoon season is likely to lengthen.
13. Extreme rain may become more intense and frequent.
14. The current slowdown in global warming will not affect long-term rise in temperatures. For instance, the global temperatures have on average risen by 0.12 degrees Celsius per decade since 1951 but the warming rate in the 1998-2012 period is considerably lower at 0.05 degrees C.
15. The IPCC report has blamed methane and nitrous oxide too for the global warming, but it named CO_2 as the factor most important.

16. The carbon dioxide concentrations have increased by 40% since pre-industrialized times, primarily from fossil fuel emissions and secondarily from net land use change emission (such as deforestation).
17. The latest report identifies **radiative forcing**, the difference between the amount of heat coming into the climate and the amount reflected back, as the immediate cause of warming. Radiative forcing is expressed in watts per square metre (W/m^2), a unit of energy. A rise indicates that heat is building up in the system.
18. Total radiative forcing from man-made sources since 1750 (i.e., before industrialisation) has risen from 0.29-0.85W/m^2 in 1950 to 0.64-1.86W/m^2 in 1980 to 1.13-3.33W/m^2 in 2011. The average has jumped from 0.57 to 1.25 to 2.29, respectively—a four-fold increase in 60 years. The best estimate for total man-made radiative forcing in 2011 is 43% above 2005 levels.
19. The atmospheric concentrations of CO2, methane and nitrous oxide have increased to levels unprecedented in at least the last 800,000 years. The largest contribution to total radiative forcing is caused by the increase in the atmospheric concentration of CO_2 since 1750.
20. Cumulative emissions of CO_2 will largely determine global mean surface warming by the late 21st century and beyond. The most optimistic of four scenarios in the report sees an average temperature rise of 1 degree C by 2100 over 2000 levels, ranging from 0.3 to 1.7 degrees C. This is the only scenario that can safely meet a UN target of 2 degree C, which also factors in warming from the start of the Industrial Revolution to 2000.

Climate change impact on India

Indian Network for Climate Change Assessment (INCCA) recently released its first report in November 2010. It is the result of collective work of 45 scientists- on the impact of climate change in four regions of the country.

These regions are:

- The Himalayan region
- The North-East
- The Western Ghats
- The coastal areas

While the report admits that significant research gaps and lack of extensive databases are hampering Indian climate science, it attempts to assess the impact of climate change by 2030 in the above four areas in the sectors of agriculture, water, health and forests. Some of the highlights of the report are as follows.

1. It projects a 1.7 to 2.2 degrees centigrade increase in annual temperatures, with the biggest increase coming in coastal regions.

2. Sea level and rainfall will also rise, with cyclones becoming more intense, though less frequent.

3. Flooding could increase up to 30 per cent.

4. Droughts may become more severe in the Himalayas.

5. Warmer weather will encourage mosquitoes, malaria could spread to new areas in the Himalayas, and see higher rates in the North East as well.

6. While irrigated rice may see marginal yield increases, maize, sorghum and apple could see reduced yields.

7. The increase in thermal humidity will lead to stress in livestock and a reduction in milk productivity.

Initiatives to control global warming

United Nations Framework Convention on Climate Change (UNFCCC)

UNFCCC is an international environmental treaty produced at the United Nations Conference on Environment and Development (UNCED), informally known as the Earth Summit, held in Rio de Janeiro in 1992. The treaty aimed at reducing emissions of greenhouse gas in order to combat global warming. The treaty as originally framed set no mandatory limits on greenhouse gas emissions; rather, the treaty included provisions for updates (called "protocols") that would set mandatory emission limits. The principal update is the **Kyoto Protocol**. Signatories to the UNFCCC are split into three groups:

1. Annex I countries (industrialised countries)

2. Annex II countries (developed countries which pay for costs of developing countries)

3. Developing countries.

The intergovernmental negotiation process consists basically of the Conference of the Parties (COP). The Conference of the Parties (COP) is the "supreme body" of the Convention, that is, its highest decision-making authority. It is an association of all the countries that are Parties to the Convention. The COP meets *every year*, unless the Parties decide otherwise.

Important COPs

Year	COP	Venue
1995	COP 1	Berlin, Germany
1997	COP 3	Kyoto, Japan
2002	COP 8	New Delhi, India
2007	COP 13	Bali, Indonesia
2008	COP 14	Poznan, Poland
2009	COP 15	Copenhagen, Denmark
2010	COP 16	Cancun, Mexico
2011	COP 17	Durban, South Africa
2012	COP 18	Doha, Qatar

2013	COP 19	Warsaw, Poland
2014	COP 20	Lima, Peru
2015	COP 21	Paris, France

Kyoto Protocol

The **Kyoto Protocol** is an amendment to the United Nations Framework Convention on Climate Change (UNFCCC), an international treaty on global warming. The Kyoto Protocol is an international agreement setting targets for industrialised countries to cut their greenhouse gas emissions. The TARGETED GASES are:

1. Carbon dioxide (CO_2)
2. Methane (CH_4)
3. Nitrous Oxide (N_2O)
4. Hydrofluorocarbons (HFCs)
5. Perfluorocarbons (PFCs)
6. Sulphur hexafluoride (SF_6)

The Kyoto Protocol was adopted at the third session of the Conference of Parties (COP) to the UNFCCC in 1997 in Kyoto, Japan. It was based on principles set out in a framework convention signed in 1992.

For the protocol to come fully into force, the pact needed to be ratified by countries accounting for at least 55% of 1990 carbon dioxide emissions. With countries like the US and Australia unwilling to join the pact, the key to ratification came when Russia, which accounted for 17% of 1990 emissions, signed up to the agreement in November 2004.

On 16th February 2005 the Kyoto Protocol finally became an international law. At the treaty's implementation in February 2005, the agreement had been ratified by 141 countries, including India, representing 61.6% of emissions.

The Kyoto Protocol operates on the principle of "*common but differentiated responsibility*". Only the industrialised nations who have signed up to the treaty are legally bound to reduce worldwide emissions of six greenhouse gases (collectively) by an average of 5.2% below their 1990 levels by the period 2008-2012.

The signatories to the Kyoto Protocol are split into three groups:

Annex I countries: They are 41 industrialised countries which have obligations to reduce their greenhouse gas emissions under the Kyoto Protocol. Their combined emissions, averaged out during the 2008-2012 period, should be 5.2% below 1990 levels.

Annex II countries: These are the countries which have a special obligation under the Kyoto Protocol to provide financial resources and transfer technology to developing countries. This group is a sub-section of the Annex I countries, excluding those which, in 1992, were in transition from centrally planned to a free market economy. They include any ex-Soviet bloc state. At the time the Kyoto Protocol was adopted in 1997, these countries were on the path from a Communist planned economy to a market economy.

Developing countries: These countries, including India, have no obligation to reduce emissions of Green House gases.

Thus, under the Kyoto Protocol the industrialised nations are legally bound to reduce worldwide emissions of six *greenhouse gases* (collectively) by an average of 5.2% below their 1990 levels by the period 2008-2012.

Individually, each country has developed its own method to meet its targets. The EU has setup a market by which 12,000 factories and power stations are given a carbon dioxide quota. If they exceed this amount they can purchase extra allowances or pay a financial penalty. If they fall below the amount they can sell on the extra quota. This is called **Cap and Trade Scheme**.

Cap and trade is an emission trading scheme under the *Clean Development Mechanism (CDM)* whereby businesses or countries can buy or sell allowances to emit greenhouse gases via an exchange. ***Clean Development Mechanism (CDM)*** is a programme that enables developed countries or companies to earn credits by investing in greenhouse gas emission reduction or removal projects in developing countries. These credits can be used to offset emissions and bring the country or company below its mandatory target.

If any of the participating countries exceed their proposed 2012 target, they will then have to make the promised reductions from the 2012 target and an additional 30% more in the next period. The EU and Japan have already promised to reduce to pollution by 8% from their respective 1990 levels.

Most of the countries in the pact agree that it will be a difficult task to meet their Kyoto targets; already nations are falling behind their targets. Spain and Portugal in the EU were 40.5% above 1990 levels in 2002. Canada, one of the first countries to sign, has increased emissions by 20% since 1990, and they have no clear plan to reach their target. Japan is also uncertain about how it will reach its 6% target by 2012.

Paris Climate Agreement

The Paris Agreement is an agreement within the United Nations Framework Convention on Climate Change (UNFCCC) dealing with greenhouse gases emissions mitigation, adaptation and finance starting in the year 2020. **It will replace Kyoto Protocol from 2020**.

The agreement was negotiated by representatives of 195 countries at the 21st Conference of the Parties of the UNFCCC in Paris in 2015 and adopted by consensus on 12 December 2015.

It was opened for signature on 22 April 2016 (Earth Day) in a ceremony in New York City.

The agreement will only enter into force provided that 55 countries that produce at least 55% of the world's greenhouse gas emissions ratify, accept, approve or accede to the agreement.

The Agreement is the first under the UNFCCC to **commit all countries** to cut carbon emissions.

It is partly legally binding and partly voluntary. The Agreement will now be open for ratification by each member nation from April 2016 onwards.

The measures in the agreement include:

- To peak greenhouse gas emissions as soon as possible and achieve a balance between sources and sinks of greenhouse gases in the second half of this century

- To keep global temperature increase "well below" 2C (3.6F) and to pursue efforts to limit it to 1.5C
- To review progress every five years
- $100 billion a year in climate finance for developing countries by 2020, with a commitment to further finance in the future.

Principal provisions in detail

1. **Temperature Increase:** Holding the increase in the global average temperature to well below 2°C above pre-industrial levels and to **pursue efforts to limit the temperature increase to 1.5°C** above pre-industrial levels, recognizing that this would significantly reduce the risks and impacts of climate change.

2. **Preservation of Forests**: Parties are encouraged to take action to implement and support reducing emissions from deforestation and forest degradation, and the role of conservation, sustainable management of forests and enhancement of forest carbon stocks in developing countries; and alternative policy approaches, such as joint mitigation and adaptation approaches for the integral and sustainable management of forests.

3. **Bearing the Cost**: As part of a global effort, developed country Parties should continue to take the lead in mobilizing climate finance from a wide variety of sources, instruments and channels, noting the significant role of public funds, through a variety of actions, including supporting country-driven strategies, and taking into account the needs and priorities of developing country Parties. Such mobilization of climate finance should represent a progression beyond previous efforts.

4. **Transparency**: In order to build mutual trust and confidence and to promote effective implementation, an enhanced transparency framework for action and support, with built-in flexibility which takes into account Parties' different capacities and builds upon collective experience is hereby established.

5. **Absence of "Greenhouse Gas Emissions Neutrality"**: In order to achieve the long-term temperature goal, Parties aim to reach global peaking of greenhouse gas emissions as soon as possible, recognizing that peaking will take longer for developing country Parties, and to undertake rapid reductions thereafter in accordance with best available science, so as to achieve a balance between anthropogenic emissions by sources and removals by sinks of greenhouse gases in the second half of this century, on the basis of equity, and in the context of sustainable development and efforts to eradicate poverty.

6. **Loss and Damage**: Parties recognize the importance of averting, minimizing and addressing loss and damage associated with the adverse effects of climate change, including extreme weather events and slow onset events, and the role of sustainable development in reducing the risk of loss and damage.

7. **Five-Year Contributions**: Each Party shall communicate a nationally determined contribution every five years and be informed by the outcomes of the global stocktake.

India's INDC

India on 1st October, 2015 submitted its *'climate action plan'* to United Nations Framework Convention of the Climate Change (UNFCCC) at Bonn in Germany.

The 'Climate Action Plan' of individual country is called the **Intended Nationally Determined Contribution (INDC)** in the realm of climate change negotiation after the last year's UNFCCC Conference of Parties at Lima (Peru).

These INDCs, comprising mitigation (emission cut promises) and adaptation measures, formed the basis of climate negotiations in Paris during 'conference of parties' (COP21) in November-December 2015.

The main features of India's INDC are as follows.

1. India would fight the climate change by increasing its energy efficiency route and reducing its 'emission intensity' (carbon emission per unit of GDP) substantially.
2. India aims to reduce the emissions intensity of its GDP by 33 to 35% by 2030 from 2005 level.
3. India has set a target to achieve about 40% cumulative electric power installed capacity from non-fossil fuel based energy resources by 2030. The non-fossil fuel based energy includes solar, wind, bio-mass and nuclear.
4. India has clarified that its INDC do not bind it to any sector specific mitigation obligation or action, including in agriculture sector.
5. India has also said that the successful implementation of its INDC would depend on cooperation from the developed countries in terms of technology transfer and capacity building. It aims to receive low cost international finance including from Green Climate Fund (GCF).
6. India will increase the carbon sink by creating an additional capacity of 2.5 to 3 billion tonnes of CO_2 equivalent through additional forest and tree cover by 2030.
7. India will review its National Missions under the National Action Plan on Climate Change (NAPCC) in the light of new scientific information and technological advances. It has identified new missions or programs on wind energy, health, waste to energy, and coastal areas. It is also redesigning the National Water Mission and National Mission on Sustainable Agriculture.
8. It will also strive to propagate a healthy and sustainable way of living based on traditions and values of conservation and moderation.
9. India has enlisted the following priority areas in its INDC:
    a. Introducing new, more efficient and cleaner technologies in thermal power generation.
    b. Promoting renewable energy generation and increasing the share of alternative fuels in overall fuel mix.
    c. Reducing emissions from transportation sector.
    d. Promoting energy efficiency in the economy, notably in industry, transportation, buildings and appliances.
    e. Reducing emissions from waste.

f. Developing climate resilient infrastructure.

g. Full implementation of Green India Mission and other programmes of afforestation.

h. Planning and implementation of actions to enhance climate resilience and reduce vulnerability to climate change.

Chapter 11: Forest types of India; Phytogeographical regions of India; Ecological and economic importance of forests; Afforestation; Deforestation and Social forestry

Forest types of India

India possesses a distinct identity, not only because of its geography, history and culture but also because of the great diversity of its natural ecosystems. The panorama of Indian forests ranges from evergreen tropical rain forests in the Andaman and Nicobar Islands, the Western Ghats, and the north-eastern states, to dry alpine scrub high in the Himalaya to the north. Between the two extremes, the country has semi-evergreen rain forests, deciduous monsoon forests, thorn forests, subtropical pine forests in the lower montane zone and temperate montane forests.

As per the *India State of Forest Report 2013* (ISFR 2013, published in 2014), the total forest and tree cover of the country is 78.92 million hectare which is 24.01 percent of the geographical area of the country.

According to the revised survey of forest types of India by Sir H.G.Champion and S. K. Seth (1968), the following ***16 forest types*** are met within India. These forest types are sub-divided into 221 minor types. Structure, physiognomy and floristics are all used as characters to define the types.

1. *Tropical wet evergreen forest:* Lofty, very dense, multilayered forest with mesophytic evergreen 45 m. or more high with a large number of species, epiphytes numerous, climbers few. Found along the Western face of the Western Ghats and in a strip running southwest from upper Assam through Cachar, and in Andamans.

Examples: (i) *Ranni, Kerala,* 1000 m. *Important species:* Mesua *(Mesuaferrea),* white cedar *(Dysoxylum malabaricum), Calophyllum,* Toon *(Cedrela toona),* dhup *(Canarium* spp.), *Palaquium, Hopea,* jamun *(Syzygium spp.),* canes.

(ii) *Cacher, Assam:* Gurjan *(Dipterocarpus turbinatus),* chaplash *(Artocarpus chaplasha),* Jamun *(Syzygium* spp.) mesua *(Mesuaferrea),* muli bamboo *(Melocanna bambusoi),*agar *(Aquilaria agallocha).*

2. *Tropical semi-evergreenforest:*A closed high forest with large dominants, some deciduous, with tendency to gregariousness, many species, buttressed trunks frequent, bark thicker and rougher and canopy less dense than in previous type, climbers heavy, bamboos less prevalent, epiphytes abundant, occurs in the Western Coast, Assam, lower slopes of Eastern Himalayas, Orissa and in Andamans.

Examples: (i) Palghat, Kerala:Aini *(Artocarpus hirsuta),* semul *(Salmalia malabarica),* gutel *(Trewianudiflora),* mundani *(Acrocarpusfraxinifolius), Hopea,* benteak *(Lagerstroemia lanceolata),* kadam *(Anthocephalus cadamba),* irul *(Xylia xylocarpa),* laurel *(Terminalia tomentosa),* rosewood *(Dalberiga latifolia),* mesua, haldu *(Adina cordifolia),* Kanju *(Holoptelia integrifolia),* bijasal *(Pterocarpus marsupium),* kusum *(Schleichera oleosa),* thorny bamboo *(Bambusa arundinacea).*

(ii) Kalimpong, West Bengal:bonsum *(Phoebe* spp.), white cedar *(Dysoxylum malabaricum),* Indian chestnut *(Castanopsis indica), Litsea,*hollock *(Terminalia myriocarpa),* champa *(Michelia champaca),* mango *(Mangifera indica).*

3. ***Tropical moist deciduous forest:***Irregular top storey of deciduous species, 40 m or more high; heavily buttressed trees, second storey with some evergreens; fairly complete shrubby undergrowth with patches of bamboos, heavy climbers including canes. Occurs throughoutAndamans, moister parts of Uttar Pradesh, Madhya Pradesh, Gujarat, Maharashtra, Karnataka and Kerala.

Examples: (i) Andamans: Pad auk *(Pterocarpus dalbergoides),* white chuglam *(Terminalia bialata),* badam *(Terminaliaprocera),* dhup *(Canarium* spp.), chikrasi *(Chikrasia tabularis),* Kokko *(Albizzia lebbek).*

(ii) Dehradun (Uttar Pradesh): Sal *(Shorea robusta),* lendi *(Lagerstroemia parviflora),* haldu *(Adina cordifolia),* pula *(Kydia calycina), Litsea,* jamun, mahul *(Bauhinia vahlii).*

4. ***Littoral and swamp forests:***Mainly evergreen species of varying density and height always associated with wetness. Littoral forests are found all along the coastal and the swamp forests in the deltas of bigger rivers.

Examples: Sunderbans, West Bengal:*Bruguiera, Sonneratia,* agar *(Aquilaria agallocha),* bhendi *(Thespesia populnea),* keora *(Pandanus tectorius), Nipa,* etc.

5. ***Tropical dry deciduous forest:*** Upper canopy closed through rather uneven, composed of a mixture a few species, practically all deciduous, during the dry season, some for several months; upto 20 m high. Some species tend to predominate over selected areas but most non-gregarious, lower canopy almost entirely deciduous, shrubs present but enough light reaches the forest floor to permit growth of grass, bamboos; climbers few but some large and woody, epiphytes and ferns inconspicuous. Occurs in an irregular wide strip from the foot of the Himalayas to Kanyakumariexcept in Rajasthan, Western Ghats and Bengal.

Examples: I. Betul (MadhyaPradesh): Teak*(Tectonagrandis),* axle wood *(Anogeissus latifolia),* tendu *(Diospyros tomentosa),* bijasal *(Pterocarpus marsupium),* rose wood *(Dalbergia latifoiia),* amaltas *(Cassia fistula),* palas *(Butea monosperma),* haldu *(Adina cordifolia),* kasi, bel *(Aelgle mannelos),* lendi *(Largerstroemia parviflora),* common bamboo, etc.

II. Cuddapah (Andhra Pradesh): Red sandlers. axle wood *(Anogeissus latifolia),* anjan *(Hardwickia binata),* harra *(Terminalia chebula),* laurel *(Terminalia tomentosa),* satinwood *(Chloroxylon swietenia),* papra *(Gardenia latifolia),* acha *(Buchanania lanzan).*

III. Rarrmagar(Uttar Pradesh): sal*(Shorea robusta),* laurel *(Terminalia tomentosa),* axlewood *(Anogeissus latifolia),* bhilma *(Semecarpus anacardium),* achar *(Buchanania lanzan),* khair *(Acacia catechu),* ghout, bet *(Aegle marmelos)* etc.

6. ***Tropical thomforest:***Thorny leguminous species predominate, trees with short boles and low branches, spiny and with xerophytic characteristics, climbers few. This type is found in southern parts of Punjab, Rajasthan, Upper Gangetic Plains, Deccan plateau and the lower peninsular India.

Examples: I. Sholapur (Maharashtra): Khairs *(Acacia catechu)*, reunjha *(Acacia leucophloea)*, axlewood *(Anogeissus latifolia)*, neem *(Azadirachta indica)*, sandalwood *(Santalum album)*, nirmali *(Strychnos potatorum)*, dhaman *(Grewia tiliaefolia)* .

II. Jaipur (Rajasthan): *Acacia senegal*, reunjha *(Acacia leucophloea)*, Khejra *(Prosopis spicigera)*, kanju *(Holoptelia integrifolia)*, neem *(Azadirachta indica)*, *Calotropis gigantea*, palas *(Butea monospenna)* etc.

7. ***Tropical dry evergreen forest:*** A low forest, upto 12 m. high with complete canopy, mostly coriaceous leaved ever-green trees of short boles, no canopy layer differentiation; bamboos rare or absent; grass not conspicuous. Restricted to a small area of Karnataka Coast which receives some summer rain also.

Example: Sriharikota (Andhra Pradesh): Khirni, jamun *(Syzygium*, spp.), kokko *(Albizzia labbek)*, ritha *(Sap indus emerginatus)*, tamarind *(Tamarindus indica)*, neem, *(Azadirachta indica)*, machkund *(Pterospennum suberifolium)*, toddy palm, gamari *(Gmelina arborea)*, canes, etc.

8. ***Sub-tropical broad leaved hill forest:***Luxuriant forest, evergreen species predominating, limited to the lower slopes of the Himalayas in Bengal and Assam and other hill ranges such as Khasi, Nilgiri and Mahabaleshwar.

Example: Trivandrum (Kerala): Jamun *(Syzygium* spp.), *Machilus, Meliosma, Elaeocarpus, Celtis*, etc.

9. ***Sub-tropical pine forest:***Practically pure association of chir pine, considerably influenced by periodical fires, no underwood, few shrubs. Found throughout the whole length of North- West Himalayas between 1000 and 1800 m.Absent in Kashmir due to weakened southwest monsoon. In Khasi, Manipur and Naga Hills khasya pine occurs at small altitudes.

Examples: Maharpali (Uttar Pradesh): Chir *(Pinus roxburghii)*, jamun *(Syzygium*spp.), oak *(Quercus* spp.), *Rhododendron* etc.

10. ***Sub-tropical dry evergreenforest:***Low practically scrub forest, small evergreen stunted trees and shrubs including thorny species, herbs, and grasses appear in monsoon. Metwithin the Bhabar, the Siwaliks and the Western Himalayas upto about 1000 m. *Examples: Acacia modesta, Pistacia* etc.

11. ***Montane wet temperate forest:*** A closed evergreen forest. Trees mostly shortboled and branchy attaining large girth, height rarely 6 m, crowns dense and rounded; leaves coriaceous, red when young; branches clothed with mosses, ferns and other epiphytes; woody climbers common. Found in the higher hills of Madras and Kerala from 150m. upwards and in Eastern Himalayas on the higher hills of Bengal, Assam and NEFA from 1800 to 3000 m.

Examples: Kalimpong (West Bengal): *Machilus, Cinnamomum, Litsea, Magnolia*, Chilauni *(Schima wallichi)*, indian chestnut *(Castanopsis indica)*, birch *(Betula utilis)*, plum etc.

12. ***Himalayan moist temperate forest:***Coniferous forest, mostly pure, 30 to 50 m. high with varying underwood mostly evergreen; mosses and ferns grow freely on trees. Extends along the entire length of the Himalayas between the pine and the sub-alpine forests in Kashmir, Himachal Pradesh, Punjab, Uttar Pradesh, Darjeeling and Sikkim between 1500 and 3300 m.

Examples: (i) Chakrata (Uttar Pradesh): Oak(*Quercus* spp.), fir *(Abies pindrow),* spruce *(Picea smithiana),* deodar *(Cedrus deodara), Celtis,* chestnut, maple.

II. Sutlej valley (Himachal Pradesh): Spruce *(Picea smithiana),* deodar *(Cedrus deodara),* fir *(Abies pindrow),* kail *(Pinus wallichiana),* oak *(Quercus* spp.), Yew *(Taxus baccata),* maple, birch *(Betula uti lis)* etc.

13. *Himalayan dry temperateforest:* Predominantly coniferous forest with xerophytic shrubs, hardly any epiphytes and climbers. Foundin the innerranges of the Himalayas where southwest monsoon is feeble, precipitation below 100 cm. mostly snow; in Ladakh; Lahoul, Chamba, Bashahr, Garhwal and Sikkim.

Example: Upper Bashahr(Himachal Pradesh): *Chilgoza(Pinus gerardialla),* deodar *(Cedrus deodara),* oak *(Quercus* spp.), maple, ash *(Fraxinus xanthoxyloides), Celtis, Parrotia,* olive *(Olea cuspida)* etc.

14. *Sub-alpine forest:* Dense growth of small crooked trees or large shrubs with coniferous trees, mostly fir and birch. Conifers 30 m. high, broad leaved trees 10 m. high. Occurs at the upper limit of tree forest in the Himalayas adjoining alpine scrub and grasslands.

Example: Kullu: Fir, *(Abies pindrow),* Kail *(Pinus wallichiana),* spruce *(Picea smithiana), Rhododendron,* plum, yew *(Taxus baccata)* etc.

15. *Moist apline scrub:*Low evergreen dense growth of *Rhododendron* and birch. Mosses and ferns on the ground with alpine shrubs and flowering herbs. Occurs along the entire length of the Himalayas above 3000 m. *Example:* Kumaun Hills (3800 m): Birch *(Betula utilis), Rhododendron, Berberis,* honey suckle *(Lonicera* spp.) etc.

16. *Dry alpine scrub:*The upper-most limit of scrub xerophytic, dwarf shrubs, over about 3,500 m. *Example:* High Himalayas over 4,000 m. Juniper *(Juniperus* spp.), honey suckle *(Lonicera* spp.), *Artemesia, Potentilla* etc.

Table 1: The 16 forest types within India

	Forest Type (Major)	Area (million hactare)	% of forest area	Occurrence in States/UTs of India
1.	Tropical wet evergreen forest	4.5	5.8	Arunachal Pradesh, Assam, Karnataka, Kerala, Mizoram, Manipur, Nagaland, Tamil Nadu, Andaman & Nicobar Islands and Goa
2.	Tropical semi-evergreen forest	1.9	2.5	Assam, Karnataka, Kerala, Maharashtra, Nagaland, Tamil Nadu, Andaman & Nicobar Islands and Goa
3.	Tropical moist deciduous forest	23.3	30.3	Andhra Pradesh, Assam, Bihar, Gujarat, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Manipur, Meghalaya, Mizoram, Tripura, Nagaland, Orissa, Tamil Nadu, Uttar Pradesh, West Bengal, Andaman & Nicobar Islands, Goa, Dadar & Nagar Haveli
4.	Littoral and swamp forest	0.7	0.9	Andhra Pradesh, Gujarat, Orissa, Maharashtra, Tamil Nadu, West Bengal, Andaman & Nicobar Islands
5.	Tropical dry deciduous forest	29.4	38.2	Andhra Pradesh, Bihar, Gujarat, Haryana, Himachal Pradesh, Kerala, Karnataka, Madhya Pradesh, Maharashtra, Jammu & Kashmir, Punjab, Rajasthan, Tamil Nadu, Uttar Pradesh
6.	Tropical thorn forest	5.2	6.7	Andhra Pradesh, Gujarat, Haryana, Himachal Pradesh, Karnataka, Madhya Pradesh, Maharashtra, Punjab, Rajasthan, Tamil Nadu, Uttar Pradesh
7.	Tropical dry evergreen	0.1	0.1	Andhra Pradesh, Tamil Nadu
8.	Sub tropical broad leaved hill forest	0.3	0.4	Assam, Meghalaya
9.	Sub tropical pine forest	3.7	5.0	Arunachal Pradesh, Manipur, Sikkim, Meghalaya, Nagaland, Himachal Pradesh, Jammu & Kashmir, Haryana, Uttar Pradesh, Punjab
10.	Sub tropical dry evergreen forest	0.2	0.2	Himachal Pradesh, Jammu & Kashmir
11.	Montane wet temperate forest	1.6	2.0	Arunachal Pradesh, Manipur, Sikkim, Nagaland Karnataka, Tamil Nadu
12.	Himalayan moist temperate forest	2.6	3.4	Himachal Pradesh, Jammu & Kashmir and Uttar Pradesh
13.	Himalayan dry temperate	0.2	0.2	Himachal Pradesh, Jammu & Kashmir
14.	Sub-alpine forest	–	–	Arunachal Pradesh, Himachal Pradesh
15.	Moist alpine-scrub	3.3	4.3	Jammu & Kashmir, Uttar Pradesh
16.	Alpine scrub	–	–	Jammu & Kashmir, Uttar Pradesh

Phytogeographical regions of India

The Indian sub-continent is characterized with a variety of climate types and the flora of the country is also correspondingly of different types in its different parts. The country has been divided into the following **nine phytogeographical regions** for the study of flora (Fig. 1).

1. **Western Himalayas.** It extends from Kumaon to Kashmir and has annual rainfall up to 200 cm. Altitudinally there are following three zones of vegetation corresponding to three climatic belts:

   (i) **Submontane zone.** This extends up to 1500 metres altitude and comprises mostly of Siwalik ranges. The forests are tropical and subtropical having trees such as *Shorea robusta, Dalbergia sissoo, Cedrela toona, Ficus glomerata, Eugenia jambolano, Acacia catechu, Butea monosperma* (dhak), *Zizyphus* and thorny succulent euphorbias on the slopes.

   (ii) **Temperate zone.** Above submontane zone extend montanetemperate forests up to 3500 metres altitude. They are dominated by plant genera such as *Quercus, Acer, Ulmus, Rhododendron, Betula, Salix, Populus, Cornus, Prunus, Fraxinus, Pinus, Cedrus, Picea* and *Taxus*.

   (iii) **Alpine zone.** This zone extends from 3500 to 4500 metres altitudes (snow line) and is characterized with alpine forest vegetation with scrub and meadows. Most common

tree species are *Abies, Betula, Juniperus* and *Rhododendron*. The herbs, which occur near the snow line, include species such as *Primula, Potentilla, Polygonum, Geranium, Saxifraga, Aster,* etc.

2. **Eastern Himalayas.** It includes regions of Sikkim and NEFA and is characterized by more rainfall, less snow and higher temperature. This is also divided into the following three zones altitudinally.

    a. **Tropical zone.** Up to 1800 metres altitudes, this zone has tropical semi-evergreen or moist deciduous forests. These forests comprise the plants such as *Shorea robusta, Acacia catechu, Delbergia sissoo, Terminalia, Albizzia, Cedrela, Dendrocalamus* (bamboo), etc.

    b. **Temperate zone.** This zone extends between 1800 metres to 3800 metres altitudes and has typical montane temperate forests, which are dominated by oaks such as *Michelia, Quercus, Pyrus, Symplocos, Eugenia,* etc., at lower levels and by conifers as *Juniperus, Cryptomeria, Abies, Pinus, Larix* and *Tsuga* and also *Salix, Rhododendron* and *Arundinaria* (bamboo) at higher cooler levels.

    c. **Alpine zone.** Beyond the temperate zone extends alpine zone up to 5000 metres altitudes. It has alpine vegetation including *Juniperus* and *Rhododendron* with its other typical flora.

3. **Indus plains.** This zone includes the arid and semiarid regions of Punjab, Rajasthan, Kutch, part of Gujarat and Delhi. The rainfall is less than 70 cm. The vegetation is tropical thorn forest in semi-arid region and is typical desert in the arid region. The plants of this zone are primarily xerophytic. The common plant species of this zone are *Acacia nelotica, Prosopis* sp., *Salvadora, Tecomella, Capparis, Tamarix, Zizyphus, Calotropis, Panicum, Saccharum, Cenchrus, Euphorbia,* etc.

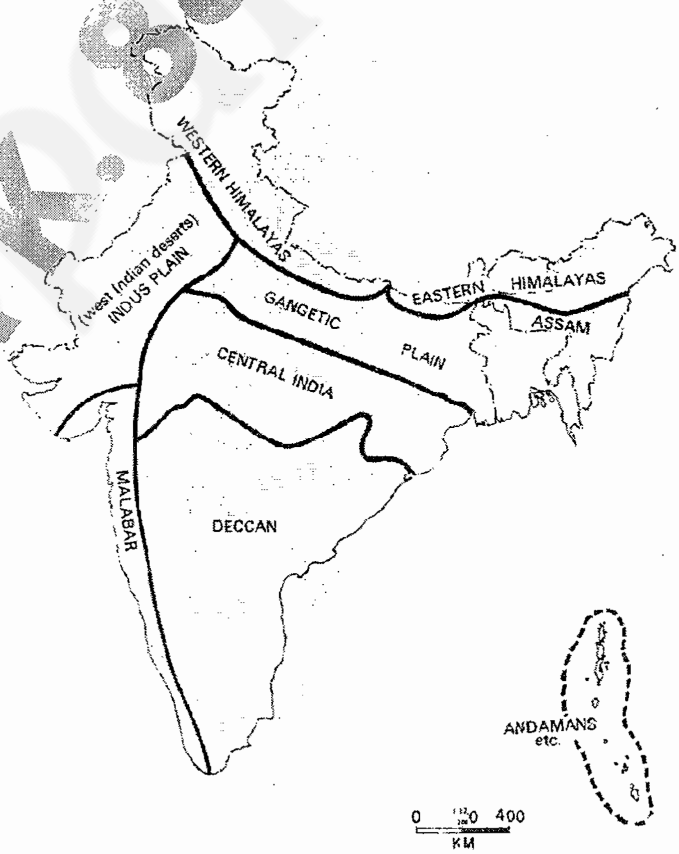


Figure 8: The phytogeographical regions of India

4. **Gangetic plains.** This region extends over Uttar Pradesh, Bihar, Bengal and part of Orissa and is characterized by moderate amount of rainfall and most fertile (*i.e.,* alluvial) soils. Vegetation of this zone is chiefly of tropical moist and deciduous and dry deciduous forest type. The common plants of this zone are *Dalbergia sissoo* (shesham), *Acacia nelotica* (babul),

Saccharum munja, Butea monosperma, Madhuca indica (mahua), *Terminalia arjuna* (arjuna), *Buchanania lanzan* (chiraunji), *Diospyros melanoxylon* (tendu) , *Cordi myxa* (lisora), *Acacia catechu* (khair), *Azadirachta indica* (neem), *Ficus bengalensis* (bergad), *Ficus religiosa* (pipal), *Mangifera indica* (mango), and weeds and grasses such as *Xanthium, Cassia, Argemone, Amaranthus,* etc. In Gangetic delta (South Bengal) mangrove vegetation is common.

5. **Central India.** It comprises Madhya Pradesh, parts of Orissa and Gujarat. The rainfall is 150 – 200 cm and its vegetation is thorny, mixed deciduous and teak type. The chief plants of this region are *Tectona grandis, Madhuca, Diospyros, Butea, Dalbergia, Terminalia, Carissa, Zizyphus, Acacia, Mangifera,* etc.

6. **Malabar (west coast)**. This region includes western coast of India from Gujarat to Cape Comorin and has heavy rainfall. The forests are tropical evergreen in west, semi-evergreen towards interior, subtropical or montane temperate evergreen forests in Nilgiris and mangroves near Bombay and Kerala coast.

7. **Deccan Plateau**. This region extends all over peninsular India (*i.e.*, Andhra Pradesh, Tamil Nadu and Karnataka) and has rainfall up to 100 cm. Its central hilly plateau has tropical dry deciduous forests of *Bowsellia serrata, Tectona grandis* and *Hardwickia pinnata,* while, the low eastern dry Coromandal Coast has tropical dry evergreen forests of *Santalum album* (chandan), *Cedrela toona* and plants such as *Acacia, Prosopis, Euphorbia, Capparis, Phyllanthus,* etc.

8. **Assam.** This region is characterized by heavy rainfall (200 to 1000 cm). The vegetation is either dense evergreen forest or sub-tropical. The evergreen forests include trees such as *Dipterocarpus macrocarpu, Mesua ferrea, Shorea robusta, Ficus elastica,* etc. bamboos as *Bambusa pallida, Dendrocalomus hamiltonii,* etc., grasses such as *Imperata cylindrica, Saccharum* sp., *Themeda* sp., insectivorous plants as *Nepenthes* sp., and also epiphytes (ferns and orchids). In the northern cooler regions, wet hill forests include plants such as *Alnus, Betula, Rhododendron, Magnolia,* etc. The hilly tracts also have pine forests of *Pinus khasiya* and *P. insularis.*

9. **Andmans.** This region possesses a varied type of vegetation; mangroves and beach forest at its coasts and evergreen forests of tall trees in the interior. Important plant species of this island are *Rhizophora, Mimusops, Calophyllum, Lagerstroemia,* etc.

Ecological & economic significance of forests

Forests play an important role in environmental and economic sustainability. They provide numerous goods and services, and maintain life-support systems essential for life on earth. Some of these life support systems of major economic and environmental importance are as follows.

Ecological significance

Forests exert an overbearing influence on life on earth. It not only provides a safe haven for a richly diverse biota but also favourably modify climatic parameters. The importance of forests is, thus, multidimensional and this makes deforestation a process with devastating and wide-ranging consequences. The significance of forests can be considered under economic, ecological and cultural significance.

Ecological roles are the most vitally important contributions of forests, which are held responsible for maintaining conditions for life on earth.

1. **Forests stabilize global climate.** They do so by profoundly influencing natural cycles, in particular, the hydrological and carbon cycles. The temporal and spatial patterns of rainfall are greatly affected by forests, as they form an essential component in the hydrological cycle. Similarly, forests – by acting in carbon sequestration as a major **Carbon Sink**– canalso influence the levels of atmospheric carbon dioxide, and therefore, the extent of greenhouse effect and global warming. More forests would naturally mean greater removal of atmospheric CO_2 during photosynthesis and a resultant reduction of this greenhouse gas in the atmosphere. In fact, large-scale afforestation has been advocated as a method to reduce greenhouse effect.

2. **They protect biodiversity.** Forests are the greatest repository of biodiversity on land, as they provide ideal conditions for the survival and growth of living organisms. The number of species per unit area is much greater in a forest than in any other terrestrial biome. For example, the tropical rainforests cover less than 7% of the earth's land surface, but harbour more than 50% of all known species. About 62% of all known plants are found in these rainforests. The growing awareness about the necessity to conserve biodiversity is helping man to realize the significance of forests too.

3. **Forests support natural ecological systems and processes.** These so called "life support systems" maintained by forests, are being disrupted by the unabated destruction of forests. Following are specific examples of how forests sustain such life support systems:

   a. Forests check soil and wind erosion, and thereby preserve the top soil.

   b. They prevent landslides.

   c. Maintain soil fertility.

   d. They prevent floods by acting as a sponge. The forest canopy breaks up and slows down the raindrops while the forest bed soaks up the water before slowly releasing it into streams. This prevents the rapid runoff of rainwater into the rivers.

   e. Forests regulate silting of water bodies including reservoirs.

   f. They improve air quality. Forests are capable of absorbing toxic gases and particulate matter. They are particularly useful in refreshing the urban air, laden with vehicular and industrial emissions.

   g. They protect watersheds and ensure perennial supplies of fresh water.

Economic significance of forests

1. It is one of the largest renewable natural resources.Forests provide a wide variety of goods and services including food, fodder, wood, rubber, latex, resins, waxes, steroids, lubricants, flavourings, dyes, incense and fibres. That, many of these substances could be harvested on a sustainable basis further enhances the long-term resource value of forests.
2. The forest biodiversityhas immense economic value. The rich flora and fauna of the forests hold the key to numerous life sustaining products, such as pharmaceuticals and

pesticides. Forest biodiversity is also a repository of genetic wealth for future breeding and transgenic programmes. This may very well be our answer to a lurching crisis on the front of food security.

3. Economic value is also derived from the ecological stabilizing function of forests. For instance, by preventing soil erosion, forests pre-empt economic inputs into erosion management, thereby translating potential expenditure into savings. However, the actual economic value of the contributions of forests in stabilizing ecosystems, modifying climate systems and maintaining life support systems, is difficult to estimate.

Cultural significance

Forests have been strongly interwoven with the cultural ethos of human civilizations. Even in today's modern materialistic society, signs of such cultural bonds persist.

1. Forests have great aesthetic value. Their green canopy and dense surroundings have always held a great appeal to the human mind.
2. Forests have great recreation and tourist value. This is evidenced by the rising popular appeal of ecotourism and wild-safaris.
3. Forests have great spiritual significance for several communities.

According to Planning Commission of India, the forests are consistently and seriously undervalued in economic and social terms. For example, a latest estimate of gross value of goods and services provided by forestry sector puts its contribution to GDP at 2.37 per cent. Though it is extremely difficult to quantify, the economic value and the eco-system services of the forests is truly vast.

Deforestation

Introduction to deforestation

Deforestation is the temporary or permanent removal of forest cover from a forested land for agriculture or other purposes. Man has used deforestation as a primary tool in furthering the cause of colonizing the land and in the process caused irreversible ecological imbalances. Deforestation has brought about the most dramatic and extensive alterations in the volume and distribution of the earth's biomass. Richly diverse forests were replaced by agricultural cropland, pastoral land, scrubland or plantations. In the past, greater impact of deforestation was felt in temperate latitudes, the Mediterranean basin and Asia. However, in times that are more recent the focus has shifted to the remaining forests, the north boreal and tropical rainforests. Widespread deforestation will have far-reaching and devastating implications such as loss of flora and fauna, changes in the microclimatic conditions inside the forests, disruptions of hydrological cycles and destabilization of global climate.

Extent and rates of deforestation

Deforestation began during the Paleolithic times, accelerated since the Neolithic age (approx. 8000 B.C.) and became extremely rapid in the last 200 years. The role of humans is illustrated well by the fact that the most disastrous levels of deforestation occurred in areas that witnessed the birth of early civilizations, such as the Mediterranean basin, the Indus valley, China and Mexico. As civilizations advanced, more areas, such as Europe, came under threat. Colonization of the New World as well as the East greatly accelerated the destruction of forests.

The extent of deforestation can easily be surmised from the comparison between the present forest cover and that during the pre-agricultural period. Ten thousand years ago, before the advent of agriculture, forests covered 6.2 billion ha or almost 50% of the total land surface on earth. Today, we are left with only 4.05 billion ha of forests and even that cover is dwindling rapidly.

In India, a phase of rapid deforestation began in the 19th century with the arrival of British colonialism. In 1823, Thomas Munro, a governor of the presidency, did away with the position of forest conservator, believing that the laws of supply and demand would encourage someone to provide forestry programs privately. This grave mistake caused India four decades of rapid logging without any tree planting. Railroads and roadways built by the British worsened the situation.

An insatiable thirst for land has shrunk India's forest cover alarmingly even in the recent times. It is estimated that between 1950 and 1980, around 50 lakh hectares of forestland was diverted for non-forestry activities. Consequently, forest cover shrunk to around 20 per cent of the country's land area as against the national goal of 33 per cent.

In India, one estimate says forests are being depleting at a rate of 1.5 million ha per year. Remote sensing data indicate that 7.2 million ha was lost during the period 1983-2004. The environmental cost of deforestation in India is estimated to be US $ 478 million. The latest information provided by the State of Forest Report 2005 (SFR 2005, released in 2008) reveals that the forest covers of the country between the present and preceding assessment (2003) suffered a marginal loss of 728 km² during the period 2002-2004. This constitutes 0.11% of the forest cover of the country. However, the environmentalists point out that there is a serious imbalance in India's eco-system because of deforestation.

On a global scale, the tropical rain forests are being destroyed at an alarming rate. However, a survey using satellite observations for the first time, calculated that the rate of destruction had increased to about 16.4 million ha annually.

The causal factors behind deforestation

Though natural causes can account for some degree of forest destruction, it is abundantly clear that most of the damage is inflicted by human activities. Exploitation of forests was inevitable, considering the richness of their resources and the human trait of enterprise. The manner and intensity of exploitation determines the durability of natural forest resources. Broadly, there are two forms of exploitation - destructive and conservative. The destructive forms of exploitation involve clear felling of trees, overgrazing, over-farming and over-hunting. On the contrary, the conservative method applies certain safeguards in the use of forests, and does not significantly alter its structure or productivity. It includes selective felling of trees, moderate levels of grazing and some recreational and tourist use. Deforestation resulting from overexploitation by the human population can be attributed to two sets of causes, the more explicit immediate causes and the less obvious underlying causes.

Immediate/Explicit Causes

1. Logging for wood (Industrial wood, Firewood and paper)
2. Land use changes
    a. Permanent and Shifting agriculture

b. Cattle ranching

c. Fish farming

d. Resettlement programmes

e. Tree and cash crop plantations

f. Mining for minerals and oils

g. Hydroelectric projects

h. Cultivation of illegal narcotics

i. Urban expansion

j. Industrial activity

3. Indirect deforestation

   a. Forest fires

   b. Insect pest attacks

   c. Diseases

   d. Climatic changes

   e. Pollution

Underlying Causes

1. Socio-economic factors

   a. Population growth

   b. Economic development

   c. Poverty and landlessness

2. Physical and Environmental factors

   a. Distribution of forests

   b. Proximity of rivers

   c. Proximity of roads

   d. Distance from urban centres

   e. Topography

   f. Soil fertility

3. Government Policies

   a. Development policies

b. Agricultural policies

c. Forestry policies

4. Historical Causes

a. Hunting gathering behaviour

b. Rise of agriculture

c. Rise of civilization

d. Spread of colonial rule

5. Industrial revolution

Concluding remarks

The forests are the earth's largest depository of natural resources and house half of the planet's dry land species. However, man's greed is destructing the fragile ecosystem and over the years, half of the world's forests have been transformed into concrete jungles. Indiscriminate felling of trees for fuel and timber or for housing and agriculture purposes has gone on unabated despite the warnings by environmentalists. This trend will have to stop without any further delay, if we want to ensure that the crest of development attained by the society and the economy remains sustained even in the years to come.

Afforestation

The concept and rationale

The planting of trees on land hitherto unoccupied by trees or forests is called afforestation.

The need for afforestation primarily arises from the fact that we the humans have been causing deforestation at terrible rates for the past three centuries or so. Deforestation has continued almost so unabated that in most regions that it is now threatening to destabilize the entire ecosystem. We have started facing severe environmental backlash for past two decades or so. As environmentalists have consistently been pointing out, the only way to undo the undesirable effects of centuries of deforestation is to undertake large-scale afforestation and arresting the ongoing deforestation at once.

Locations for afforestation

Trees are planted on available land, mainly public land. Ideally, areas contiguous with forestland are chosen for afforestation, although it can be carried out on hill slopes, roadsides, and recreational parks, around and along water bodies or even on wasteland. In India, it is unlikely that agriculture land will be available for expansion of forest cover, other than those where agroforestry is being practised. The potential areas on which forest cover can be expanded through afforestation in India are the *culturable wastelands*, covering 13.94 million ha and part of the *fallow land and other than current fallows*, covering 9.89 million ha.

Plant species for afforestation

Species are always taken after considering the local soil and climatic factors. Both indigenous and exotic species are employed depending on the conditions. However, the use of useless exotic

species such as *Acacia, Eucalyptus and Casuarina* has been criticized in the recent years. The net result is the destruction of natural habitats. Afforestation based on exotic species may not succeed in every area, since it increases the demand for water and soil nutrients. The effect it may have on the localconditions should be carefully assessed before launching such programmes.

In the case of reforestation, there is a tendency to adopt monoculture methods in afforestotion too, with undesirable consequences.

Institutional set-up for afforestation in india and recent initiatives

In India, The National Afforestation and Eco-development Board (NAEB) was set up in August 1992 under the Ministry of Environment and Forests, for promoting afforestation, tree planting, ecological restoration and eco-development activities in the country. Special attention is being given to the regeneration of degraded forest areas and lands adjoining forest areas, national parks, sanctuaries and other protected areas as well as the ecologically fragile areas like the Western Himalayas, Aravallis, Western Ghats etc.

Major eco-restoration work involving afforestation, pasture development, and soil and water conservation has been undertaken by the NAEB in ecologically sensitive states such as J&K, UP and Rajasthan. The implementation strategy of the NAEB schemes during the 11th Five Year Plan includes Joint Forest Management, Microplanning, Incorporation of Improved technologies, Monitoring, and Evaluation of projects.

National Afforestation Programme (NAP) Scheme is the flagship scheme of NAEB, in so much as it provides support, both in physical and capacity building terms, to the Forest Development Agencies (FDAs) which in turn are the main organ to move forward institutionalization of Joint Forest Management. The FDA has been conceived and established as a federation of Joint Forest Management Committees (JFMCs) at the Forest Division level to undertake holistic development in the forestry sector with people's participation. This is a paradigm shift from the earlier afforestation programmes wherein funds were routed through the State Governments. This decentralized two-tier institutional structure (FDA and JFMC) allows greater participation of the community, both in planning and implementation, to improve forests and livelihoods of the people living in and around forest areas.

Progress/ Achievements made during the past few years have been as follows:

1. Seven hundred and fifteen FDAs have been operationalised so far to treat a total area of 9.24 lakh ha. (as on October 31, 2006).
2. Rehabilitation of jhumlands (shifting cultivation) have been given specific focus under the programme, and so far 19 jhum projects have been sanctioned in North-Eastern (NE) States and one in Orissa.
3. As on October 31, 2006, Rs. 109.46 crores was released to FDAs during the year for implementation of National Afforestation Programme.

Greening India is a compensatory afforestation initiative under which a sum of Rs. 5,000 crore has now been collected. The sum is now lying in a corpus fund with the Compensatory Afforestation Fund Management and Planning Authority (CAMPA). The fund comprises monies collected for compensatory afforestation as mandated by the Forest Conservation Act and from realization of the Net Present Value (NPV), a levy based on valuation of the forestland diverted

for non-forestry activities. The Ministry of Environment and Forests (MoEF), for the moment, is the custodian of this huge corpus.

Social Forestry

Introduction

Social forestry is afforestation outside the conventional forest area for the benefit of rural and urban communities. The main objective is to:

1. Bring in more areas under tree cover,
2. Improve the environment for protecting agriculture from adverse climatic factors,
3. Increase the supply of fuel wood for domestic use, small timber for rural housing, fodder for livestock, and minor forest produce for local industries, thereby reducing the pressure on the traditional forest area.
4. Increase the natural beauty of the landscape;
5. Create recreational forests for the benefit of rural and urban population,
6. Provide jobs for unskilled workers and
7. Reclaim wastelands.

Finally, its object is to raise the standard of living and quality of life of the rural and urban people.

History of social forestry in India

The National Commission on Agriculture, Government of India, first used the term 'social forestry' in 1976. It was then that India embarked upon a social forestry project with the aim of taking the pressure off the forests and making use of all unused and fallow land. Government forest areas that are close to human settlement and have been degraded over the years due to human activities needed to be afforested. Trees were to be planted in and around agricultural fields. Plantation of trees along railway lines and roadsides, and river and canal banks were carried out. They were planted in village common land, Government wasteland and Panchayat land.

This concept of village forests to meet the needs of the rural people is not new. It has existed through the centuries all over the country but it was now given a new character.

The need for social forestry in India

The need for a social forestry scheme was felt as India has a dominant rural population that still depends largely on fuel wood and other biomass for their cooking and heating. This demand for fuel wood will not come down but the area under forest will reduce further due to the growing population and increasing human activities.

Social forestry is an important intervention here that aims at raising plantations by the common man so as to meet the growing demand for timber, fuel wood, fodder, etc, thereby reducing the pressure on the traditional forest area.

Moreover, social forestry recognizes the local communities' rights to forest resources, and is now encouraging rural participation in the management of natural resources. Through the social forestry scheme, the government has involved community participation, as part of a drive towards afforestation, and rehabilitating the degraded forest and common lands.

Types of social forestry

Social forestry scheme can be categorized into groups :

1. farm forestry
2. community forestry
3. extension forestry
4. agro-forestry
5. recreational

Farm Forestry

At present in almost all the countries where social forestry programmes have been taken up, both commercial and non-commercial farm forestry is being promoted in one form or the other. Individual farmers are being encouraged to plant trees on their own farmland to meet the domestic needs of the family. In many areas, this tradition of growing trees on the farmland already exists. Non-commercial farm forestry is the main thrust of most of the social forestry projects in the country today. It is not always necessary that the farmer grows trees for fuel wood, but very often, they are interested in growing trees without any economic motive. They may want it to provide shade for the agricultural crops; as wind shelters; soil conservation or to use wasteland.

Community Forestry

Another scheme taken up under the social forestry programme is the raising of trees on community land and not on private land as in farm forestry. All these programmes aim to provide for the entire community and not for any individual. The government has the responsibility of providing seedlings, fertilizer but the community has to take responsibility of protecting the trees. Some communities manage the plantations sensibly and in a sustainable manner so that the village continues to benefit. Some others took advantage and sold the timber for a short-term individual profit. Common land being everyone's land is very easy to exploit. Over the last 20 years, large-scale planting of Eucalyptus, as a fast growing exotic, has occurred in India, making it a part of the drive to reforest the subcontinent, and create an adequate supply of timber for rural communities under the augur of 'social forestry'.

Extension Forestry

Planting of trees on the sides of roads, canals and railways, along with planting on wastelands is known as 'extension' forestry, increasing the boundaries of forests. Under this project there has been creation a of wood lots in the village common lands, government wastelands and panchayat lands.

Schemes for afforesting degraded government forests that are close to villages are being carried out all over the country.

Agro- Forestry

Planting of trees on and around agricultural boundaries, and on marginal, private lands, in combination with agricultural crops is known as agro-forestry.

Agroforestry is the system of land use that combines growing and raising of crops and/or livestock along with plants that belong to the forest. The land can be used to raise agricultural crops and trees and to rear animals. Some examples are shifting cultivation, growing of tea and coffee under the shade of trees, inter-cropping under coconut trees, and home gardens. In fact, most farmers in India grow agricultural crops, rear animals, and plant certain trees on their land, often on the boundary area.

Agroforestry reduces the farmers' dependency on forests even as it provides them economic benefits. It results in more diverse, healthy, and sustainable land-use systems. It focuses on meeting the economic, environmental, and domestic needs of people on their private lands. For hundreds of years, farmers have nurtured trees in their fields, pasturelands, and around their homes.

Recreational Forestry

This type of forestry is also known as aesthetic forestry. The main objective of recreational forestry is not to produce timber, fuel etc. but to meet the recreational needs by raising flowering trees and shrubs. Such forestry has high scenic value and these attacts tourists also. Trees of ornamental varieties, which flower and fruit in different seasons are planted along roadsides and canal bunds near towns and cities. It emphasizes on beautification of domestic compounds, roads and vacant lands.

Social forestry, schemes that have been started all over the country have made a considerable difference in overall forest cover in a short time.

Trees for social forestry

According to the FAO, recent estimate of land under forest in India is thought to be 51.7 mha and 18.9 mha for natural forest and plantations respectively. Plantations, therefore account for over 25% of total forest area, of which *Eucalyptus* is the most popular choice, though some other trees, such as *Cassia* spp and *Acacia* spp are also used.

A particular tree cannot be used for every land pattern and scheme identified for social forestry. Depending upon the nature of the land available for plantation, the tree species can be selected. Species of the following tree genera have been commonly used for community forestry programmes.

Eucalyptus, Acacia, Cassia, Sesbania, Melia, Azadirachta, Leucaena, Tectona, Shorea, Moringa, Annona, Zizyphus, Tamarindus, Anacardium, Dendrocalamus, Dalbergia, Terminalia, Populus, Prosopis, Lantana, Albizzia, Casuarina, Salix, Alnus and *Hardwickia.*

Advantages of social forestry

1. Provides opportunities for reforestation,
2. Enables local village-level management of soil and water conservation, Promotes the maintenance or even enhancement of biodiversity,
3. Enhances the possibility for tourism and ecotourism,
4. Contributes to the livelihood of the poor by providing food supplements, wood for construction, firewood and fodder,
5. Increases locally available jobs and income.

Thus, social forestry is an important option for forest resource management with a local development outlook, and due to its emphasis on participatory management, it can go a long way in conserving endangered forests.

Chapter 12: Concept of Sustainable Development

Introduction

Sustainable development is an effort to marry the ideas of ***sustainability*** and ***development***. Development means improving people's lives and Sustainability means living on the earth's renewable resources without damaging the ecological processes that support us all. Sustainable development is commonly defined as the development that "meets the needs of the present without compromising the ability of future generations to meet their own needs."

The sustainable development based on the assumption that societies need to manage three types of capital (economic, social, and natural), which may be non-substitutable and whose consumption might be irreversible.

The term 'sustainable development' rose to significance after it was used by the Brundtland Commission in its 1987 report *Our Common Future*. In the report, the commission coined what has become the most often-quoted definition of sustainable development: "development that meets the needs of the present without compromising the ability of future generations to meet their own needs."

Objectives of sustainable development

Sustainable development has some forward looking and broad based objectives which transcend class, caste, language and regional barriers These objectives are the charter for liberating one's economy from the clutches of exploitative mindset which has deprived nations and defied their biomass wealth. These objectives are :

- To maintain the standard of living of the largest number of people with equity and justice.
- To conserve and protect earth's natural resources from misuse and wasteful consumption.
- To innovate new technology and scientific techniques which work in unison with laws of nature and not opposed to it.
- To respect diversity and involve local and indigenous communities for a more grassroots oriented and relevant development policies.
- To decentralize governance institutions and make them more resilient, transparent and accountable to people.
- To plant international institutions which recognise the requirements of poor nationas and support them to achieve their growth targets without destroying their natural wealth and environment.
- To seek peaceful coexistence of all nations of the world

Sustainable development is thus a value based concept which appeals to the universal themes of mutual coexistence and respect for others.

Parameters of Sustainable Development

Parameters of sustainable development refers to the guiding principles that help to understand the concept of sustainable development and point out the problems associated with it and also to

help to take policy measures based on them. The parameters include Carrying capacity, Inter and Intra- generational equity, gender disparity and diversity.

Carrying Capacity

The **carrying capacity** of a biological species in an environment is the maximum population size of the species that the environment can sustain indefinitely, given the food, habitat, water and other necessities available in the environment. In population biology, carrying capacity is defined as the environment's maximal load, which is different from the concept of population equilibrium. The famous American wildlife conservation ecologist Aldo Leopol described carrying capacity in 1933 as a saturation point at which the numbers of a particular species of grazing animals approached the point where a grasslands could support no more individuals without a general and continuing decline in the quality of the pasture land. While chemical fertilizers, insecticides and pesticides increase crop yeild, their use beyond the carrying capacity of land may destroy crops.

For the human population, more complex variables such as sanitation and medical care are sometimes considered as part of the necessary establishment. As population density increases, birth rate often decreases and death rate typically increases.

Factors that affect carrying capacity are as follows.

Factors that increase	**Factors that decrease**
Decrease in per capita resource use	Environmental degradation
Technology Advance	Depletion of non-renewable resource
Decrease in resource demand	Extinction of a bio-resource
Changing environmental factors	Introduction of new compititors

Inter-generational equity

Intergenerational equity and justice refers to the use of earth's resources between generations in a manner that the present generation does not consume it completely to its exhaustion. It is the foundation of sustainability which means fairness and justice to all. It explores whether all people have similar rights, opportunities and access to all forms of community capital. It has to do with fairness between current and the future members of a community.

Intragenerational Equity

This concept of equity in resource use is the fairness in utilisation of resources among human memebers of present generations, both domestically and globally.

Equity can also be applied across communities and nations within one generation. The reason that intragenerational equity is a key principle of sustainable development is that inequities are a cause of environmental degradation. Poverty deprives people of the choice about whether or not to be environmentally sound in their activities.

The Brundtland Commission stated:

"Those who are poor and hungry will often destroy their immediate environment in order to survive: They will cut down forests; their livestock will overgraze grasslands; they will overuse marginal land; and in growing numbers they will crowd into congested cities."

Diversity (Social, Cultural knowledge and Biological diversity)

The social and cultural diversity of the world can be judged from the fact that there are around 820 ethnic groups in 160 countries.

Around four percent of the indigenous people live in areas that are highly diverse in the composition of their flora and fauna. A community is the custodian of local values in the use of local resources because it knows best the value of the resources. Once they are displaced, the outsiders bring in their technology for the extraction and ruthlessly overuse the precious and limited earth resources. Preserving the indigenous territorial rights thus protects biodiversity and the local culture, including knowledge and resource-management skills with potentially wide application.

The Earth Summit in 1992 recognised the intrinsic relationship between local communities and the environment. Agenda 21 specified that the local communities or natives should be treated as custodians of their environment and the natural resources. This led to a task force on indigenous people and the declaration of 1993 as the *International Year of the Indigenous People*. Subsequently, the World Summit on Sustainable Development at Copenhagen in 1995 brought that the social growth of the people in to the central theme of development.

Conclusion

Sustainable development addresses environmental issues, while also providing opportunities for economic growth and social responsibility. Incorporating sustainable development principles into developmental projects allows for environmental, economic, and social benefits beyond what are usually achieved.

Current updates: UN's SDGs

Recently, a blueprint was produced by the United Nations Open Working Group on Sustainable Development Goals. It takes into account the current realities and makes several modifications to the earlier goals. Heads of state at the United Nations from Sept. 25-27, 2015 adopted the new **17 proposed Sustainable Development Goals** to replace the MDGs. Significant new additions are goals concerning food security, life-long learning opportunities for all, universal social protection with a minimum floor level, and resilient infrastructure.

A brief infographic on Sustainable Development Goals is provided below.

What are the Sustainable Development Goals?

A set of **17 goals and 169 targets** covering the next 15 years that will replace the Millennium Development Goals which expire this year

What's new and different about the SDGs?

The SDGs are intended to be universal, **applying to all countries** rather than just the developing world. They emphasise the need to urgently tackle climate change

Conserve life below water | Promote life on land | Protect the planet | Good jobs and economic growth | Innovation and infrastructure | Reduced inequalities

WHY DO WE NEED NEW GLOBAL GOALS?

800m people still live in extreme poverty and suffer from hunger

144m people were displaced by natural disasters between 2008 and 2012

40% of the global population is affected by water scarcity

946m people still practise open defecation

- **6 in 10** young women and men aged 15-24 are unemployed in 2015
- **795m** people are estimated to be undernourished
- **90m** children under age five are still undernourished and stunted
- **16%** of the rural population do not use improved drinking water sources
- **50%** of people living in rural areas lack improved sanitation facilities
- **5.2m** hectares of forest were lost in 2010, about the size of Costa Rica
- **57m** children of primary school age are not in school

Quality education | Gender equality | End poverty

Good health | No hunger | Ensure Peace and justice | Partnership for the goals | Responsible consumption | Clean water and sanitation | Sustainable cities and communities | Clean energy

Chapter 13: Endangered plants, Endemism, IUCN categories, Red Data Books; Protected Area Network; Invasive species

Endangered plants of India

What is an endangered species?

An **endangered species** is a population of organisms which is facing a very high risk of becoming extinct in near future because it is either few in numbers, or threatened by changing environmental or predation parameters.

Endangered is a threat category of the International Union for Conservation of Nature (IUCN).

The position of endangered in the entire set of IUCN threat categories is as follows.

- **Extinct**: The death of the last individual of the species
- **Extinct in the wild**: Captive individuals survive, but there is no free-living, natural population.
- **Critically endangered**: Faces an extremely high risk of extinction in the immediate future.
- **Endangered**: Faces a very high risk of extinction in the near future.
- **Vulnerable**: Faces a high risk of extinction in the medium-term.
- **Near threatened**: May be considered threatened in the near future.

Endangered plants of India

India is rich in flora. Available data place India in the tenth position in the world and fourth in Asia in plant diversity.

From about 70 per cent geographical area surveyed so far, *47,000 species of plants have been described by the Botanical Survey of India* (BSI), Kolkata. The vascular flora, which forms the conspicuous vegetation cover, comprises 15,000 species. Of these, more than 35 per cent is endemic and has so far not been reported anywhere in the world. The flora of the country is being studied by the BSI.

Situation of endangered plants in India according to BSI Red Data Book

BSI brings out an inventory of endangered plants in the form of a publication titled **Red Data Book**.

The Red Data Book is the report established for documenting rare and endangered species of animals, plants and fungi as well as some local sub-species that exist within the territory of the state or country. This book provides central information for studies and monitoring programmes on rare and endangered species and their habits.

Owing to destruction of forests for agricultural, industrial and urban development, several Indian plants are facing extinction.

About 1,336 plant species are considered vulnerable and endangered. About 20 species of higher plants are categorised as possibly extinct as these have not been sighted during the last 6-10 decades.

Situation of endangered plants in India according to IUCN Red List of Threatened Species

In June 2012, The Red List of Threatened Species, prepared by the International Union for Conservation of Nature (IUCN), has listed 132 species of plants and animals as Critically Endangered, the most threatened category, from India.

Plants seemed to be the most threatened life form with 60 species being listed as Critically Endangered and 141 as Endangered.

List of some important endangered plant species of India (Based on BSI Red Data Book)

- *Actinodaphne bourneae*
- *Actinodaphne salicina*
- *Atuna indica*
- *Canthium ficiforme*
- *Capparis pachyphylla*
- *Cinnamomum chemungianum*
- *Cynometra travancorica*
- *Dimorphocalyx beddomei*
- *Dipterocarpus alatus*
- *Dipterocarpus indicus*
- *Dysoxylum beddomei*
- *Eugenia discifera*
- *Euphorbia epiphylloides*
- *Ficus andamanica*
- *Hopea parviflora*
- *Ilex venulosa*
- *Mangifera andamanica*
- *Mangifera nicobarica*
- *Memecylon subramanii*
- *Myristica magnifica*
- *Syzygium beddomei*

IUCN Categories & Red Data Book

About IUCN

The International Union for Conservation of Nature (IUCN) is **an international organization dedicated environment, diversity and development challenges**. IUCN is the world's oldest and largest global environmental network. The Union's headquarters are located in Gland, near Geneva, Switzerland.

The organization publishes the **IUCN Red List**, compiling information about threatened species and ranking them according to the severity of threat.

Conserving biodiversity is central to the mission of IUCN. It supports scientific research, manages field projects all over the world and brings Governments, non-government organizations, United Nations agencies, companies and local communities together to develop and implement policy, laws and best practice.

IUCN categories

The **IUCN Red List of Threatened Species**, founded in 1963, is the world's most comprehensive inventory of the global conservation status of biological species.

The IUCN Red List is set upon precise criteria to evaluate the extinction risk of species and subspecies. These criteria are relevant to all species and all regions of the world.

Based on the application of these criteria, the IUCN categorises the species according to their threat status.

The IUCN Red List Categories and Criteria were extensively reviewed between 1997 and 1999. The revised Categories and Criteria (**IUCN Red List Categories and Criteria version 3.1**) were adopted by IUCN Council in February 2000 and the revised system came into use in 2001. All assessments submitted to the IUCN Red List use this system. In the present form, the structure of the IUCN categories is as shown in *Fig. 1*.

In the latest - 2012 IUCN Red List of Threatened Species, the following categories are recognised.

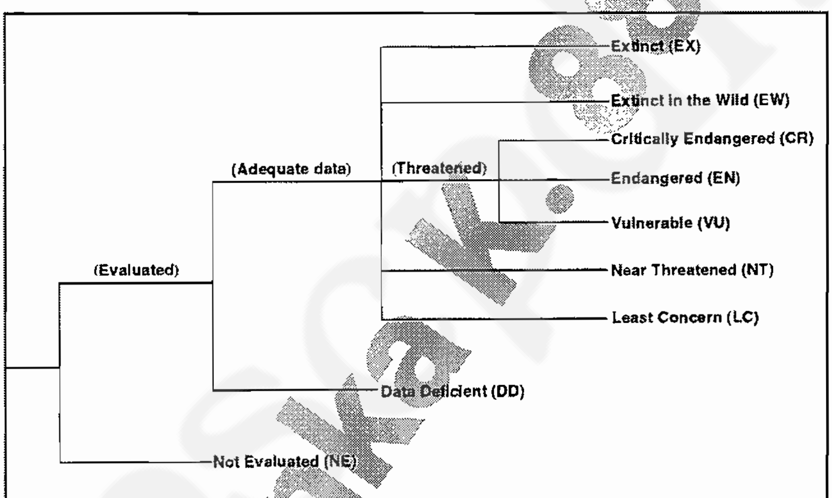


Figure 9: Structure of the IUCN categories

- **Extinct** (EX) – No known individuals remaining.
- **Extinct in the Wild** (EW) – Known only to survive in captivity, or as a naturalized population outside its historic range.
- **Critically Endangered** (CR) – Extremely high risk of extinction in the wild.
- **Endangered** (EN) – Very high risk of extinction in the wild.
- **Vulnerable** (VU) – High risk of endangerment in the wild.
- **Near Threatened** (NT) – Likely to become endangered in the near future.
- **Least Concern** (LC) – Lowest risk. Does not qualify for a more at risk category. Widespread and abundant taxa are included in this category.
- **Data Deficient** (DD) – Not enough data to make an assessment of its risk of extinction.

- **Not Evaluated** (NE) – Has not yet been evaluated against the criteria

Threatened species of India according to the latest - 2012 IUCN Red List of Threatened Species

Critically Endangered: The 2012 Red list of Threatened Species, prepared by IUCN, has listed 132 species of plants and animals as Critically Endangered, the most threatened category, from India. The Critically Endangered list included 18 species of amphibians, 14 fishes and 10 mammals. There are also 15 bird species in the category.

Endangered: The agency listed 310 species as Endangered ones, including 69 fishes, 38 mammals and 32 amphibians.

Extinction: Two plant species were reported to be extinct in the wild, including the *Euphorbia mayuranthanii* of Kerala. A leaf frog species and six plants were recorded as extinct, according to the latest assessment.

Plants: Plants seemed to be the most threatened life form with 60 species being listed as Critically Endangered and 141 as Endangered.

Birds: The threat level of as many as seven Indian bird species had increased in the last one year. According to the latest figures, 15 species of Indian birds, including the great Indian bustard, Siberian crane and sociable lapwing are there in the list of Critically Endangered birds. In the lower risk categories, the agency included 14 bird species as Endangered and 51 as vulnerable ones.

The Red Data Book of India

Botanical Survey of India (BSI) brings out an inventory of endangered plants in the form of a publication titled **Red Data Book.**

The first volume of the Red Data Books on Indian plants, edited by M.P. Nayar and A.R.K. Sastry was published by the Botanical Survey of Indian in 1987.

The Red Data Book is the report established for documenting rare and endangered species of animals, plants and fungi as well as some local sub-species that exist within the territory of the state or country. This book provides central information for studies and monitoring programmes on rare and endangered species and their habits.

Owing to destruction of forests for agricultural, industrial and urban development, several Indian plants are facing extinction.

About 1,336 plant species are considered vulnerable and endangered. About 20 species of higher plants are categorised as possibly extinct as these have not been sighted during the last 6-10 decades.

Some of the endangered flora of India according to the Red Data Book is as follows.

1. *Abies dlavayi* (Pinaceae)
2. *Artemesia amygdolina* (Asteraceae)
3. *Atropa acuminata* (Solanaceae)

4. *Colchicum luteum* (Liliaceae)
5. *Nepenthes khasiana* (Nepenthaceae)
6. *Rauwolfia serpentina* (Apocynaceae)
7. *Vanilla pilifera* (Orchidaceae)
8. *Santalum album* (Santalaceae)

Protected Areas Network

In situ conservation of wildlife and rare flora in India is supported by a comprehensive system of protected areas.

The *Wildlife (Protection) Act, 1972* provides for establishment of Protected Areas in India. There are different categories of protected areas which are managed with different objectives for the larger objectives for conservation and also for bringing benefits to the society.

Chapter – IV of the *Wildlife (Protection) Act, 1972* deals with the protected areas in India. Under the law, there are **4 types of protected areas** which can be established.

1. **Sanctuaries**
2. **National Parks**
3. **Conservation Reserves**
4. **Community Reserves**

Protected Areas of India (as on July, 2016)

Protected Areas of India	No.	Total Area (km^2)	Coverage % of Country
National Parks (NPs)	103	40500.13	1.23
Wildlife Sanctuaries (WLSs)	537	118005.30	3.59
Conservation Reserves (CRs)	67	2349.38	0.07
Community Reserves	26	46.93	0.001
Protected Areas (PAs)	**733**	**160901.74**	**4.89**

A brief description of the protected area is provided below.

Sanctuary

Under the law, the State Government may, by notification, declare its intention to constitute any area except an area comprised with any reserve forest or the territorial waters as a sanctuary if it considers that such area is of adequate ecological, faunal, floral, geomorphological, natural or zoological significance, for the purpose of protecting, propagating or developing wildlife or its environment.

A sanctuary has the following salient features.

- Generally species-oriented
- Size range is 0.61 to 7818 sq. km. Most common (in about 40%) is 100 to 500 sq. km. In 25% is 500 to 1000 sq. km.
- Boundaries may not be clearly defined or fenced
- Limited biotic interference permitted subject to restrictions, for example:
    - The Chief Wildlife Warden may grant to any person a permit to enter or reside in a sanctuary for all or any of the following purposes, namely: investigation or study of wildlife and purposes ancillary or incidental thereto; photography; scientific research; tourism; transaction of lawful business with any person residing in the sanctuary.
    - No person shall be allowed to light fire, carry fire-arms or hazardous substance into a sanctuary.
    - No person shall remove any wild animal or plant from a sanctuary.

National Parks

Whenever it appears to the State Government that an area, whether within a sanctuary or not, is, by reason of its ecological, faunal, floral, geomorphological, or zoological association or importance, needed to be constituted as a National Park for the purpose of protecting and propagating or developing wildlife therein or its environment, it may, by notification, declare its intention to constitute such area as a National Park.

The salient features of National Parks are as follows.

- Hitched to the habitat for particular wild animal species like tiger, lion, rhino etc.
- In India, the size range is 0.04 to 3162 sq.km. Most common (in about 40%) is 100 to 500 sq. km. In 15% is 500 to 1000 sq. km.
- Boundaries clearly defined and circumscribed by legislation. No alteration of the boundaries of a National Park shall be made except on a resolution passed by the Legislature of the State.
- Except the buffer zone, no biotic interference.
- No person can, destroy, exploit, or remove any wildlife from a National Park or destroy or damage the habitat or any wild animal or deprive any wild animal or its habitat within such National Park except under and in accordance with a permit granted by the Chief Wildlife Warden.
- No grazing of any livestock is permitted in a National Park and no livestock is allowed to enter except where such livestock is used as a vehicle by a person authorised to enter such National Park.

Conservation Reserve & Community Reserve

Conservation Reserves and Community Reserves in India are protected areas which **act as buffer zones to or connectors and migration corridors** between established National Parks, Wildlife Sanctuaries and reserved and protected forests of India.

Such areas are designated as conservation areas if they are uninhabited and completely owned by the Government of India but used for subsistence by communities and community areas if parts of the lands are privately owned. Administration of such reserves would be through local people and local agencies like the Gram Panchayat, as in the case of community forests.

These protected area categories were first introduced in the *Wildlife (Protection) Amendment Act 2002* - the amendment to the Wildlife Protection Act of 1972. These categories were added because of reduced protection in and around existing or proposed protected areas due to private ownership of land, and land use.

An example was the Melghat Tiger Reserve where a large surrounding area was left unprotected due to private ownership.

It provides a flexible system to achieve wildlife conservation without compromising community needs. Tiruvidaimarudur Conservation Reserve (declared on February 14, 2005) is the First Conservation Reserve to be established in the country. It is an effort of a village community who wanted to protect the birds nesting in their village.

Keshopur Chhamb Community Reserve in Gurdaspur District of Punjab, declared in 2007, is the first Community Reserve in the country.

Other in-situ conservation areas

In addition to the above, India also has **18 Biosphere Reserves**, as listed below.

Name	State
1. **Nilgiri Biosphere Reserve**	Tamil Nadu, Kerala and Karnataka
2. **Nanda Devi**	Uttarakhand
3. **Nokrek**	Meghalaya
4. **Gulf of Mannar**	Tamil Nadu
5. **Sunderbans**	West Bengal
6. **Manas**	Assam
7. **Great Nicobar Biosphere Reserve**	Andaman and Nicobar Islands
8. **Simlipal**	Orissa
9. **Dibru-Saikhowa**	Assam
10. **Dehong Deband**	Arunachal Pradesh
11. **Pachmarhi Biosphere Reserve**	Madhya Pradesh
12. **Kanchanjunga**	Sikkim

13. **Agasthyamalai Biosphere Reserve**	Kerala
14. **Achanakamar-Amarkantak**	Madhya Pradesh,Chattisgarh
15. **Rann of Kuchch**	Gujarat
16. **Cold Desert**	Himachal Pradesh
17. **Seshachalam Hills**	Andhra Pradesh
18. **Panna**	Madhya Pradesh

Further, **50 Tiger Reserves** and **30+ Elephant Reserves** have been designated for species specific management of tiger and elephant habitats.

UNESCO has designated five Indian protected areas as World Heritage Sites, in view of their uniqueness and richness in flora and fauna.

Endemism

Endemism is the association of a biological taxon with a unique and well-defined geographic area. While an island is the most sharply delineated geographic zone that may comprise endemic status, any effective geographic barriers may define boundaries of endemism; examples of such boundaries are: mountain range, river, transition to desert or other new biome. Even though the concept of endemism is often used in association with geopolitical boundaries (e.g..endemic to India, Australia etc.), the underlying association is almost always rather an area delimited by one or more natural boundaries; for example, the statement that *Welwitschia mirabilis* is endemic to the Namib Desert is a more meaningful designation than the plant being endemic to Namibia and Angola.

Organisms that are indigenous to a place are not endemic to it if they are also found elsewhere. The extreme opposite of endemism is cosmopolitan distribution.

Types of endemism

There are two subcategories of endemism –

1. ***Paleoendemism***: Paleoendemism refers to species that were formerly widespread but are now restricted to a smaller area.
2. ***Neoendemism***: Neoendemism refers to species that have recently arisen such as through divergence and reproductive isolation, or through hybridization and polyploidy in plants.

Factors leading to endemism

Endemic types or species are especially likely to develop on geographically and biologically isolated areas such as islands and remote island groups, such as Hawaii, the Galápagos Islands, and Socotra; they can equally develop in biologically isolated areas such as the highlands of Ethiopia, or large bodies of water far from other lakes, like Lake Baikal.

Factors promoting endemism are uniqueness of meteorology, soils and presence of other species that may be predators, prey or symbionts, or merely provide nesting or cover areas.

Any set of natural barriers that effective delimiters of a species distribution may contribute to endemism. When physical or environmental separation isolates taxa for a long time period, a species can develop phenotypic differentiation from other species members; this process usually occurs upon one or more mutation events that produces DNA material which enables the new phenotype to adapt better to the environment than its ancestors; the entire process can be considered as speciation and natural selection. Eventually, a new species or subspecies or a variety may emerge which will be endemic.

Endemic plants of India

Among some 7000 endemic vascular plants are such orchids as *Paphiopedilum druryi*, *Schoenorchis manipurensis*, *Phalaenopsis speciosa*, and the genus *Smithsonia*. Endemic genera include an aroid *Anaphyllum*, a palm *Bentinckia*, *Agasthiyamalaia*, *Blepharistemma*, *Cynarospermum*, *Erinocarpus*, *Adenoon*, *Lamprachaenium*, *Meteoromyrtus*, *Haplanthodes*, *Moullava*, *Otonephelium*, *Jerdonia*, and *Pinda*. Other endemic plants include the Neelakurinji, the Forest Spider Lily, the Siroi Lily, a banana *Musa velutina*, *Geranium clarkei*, the Surangi, *Impatiens tomentosa*, *Rhododendron macabeanum*, and the Khasi Pitcher Plant.

Significance of endemism

Endemics can easily become endangered or extinct if their restricted habitat changes, particularly but not only due to human actions, including the introduction of new organisms. There were millions of both Bermuda petrels and "Bermuda cedars" (actually junipers) in Bermuda when it was settled at the start of the seventeenth century. By the end of the century, the petrels were thought extinct. Cedars, already ravaged by centuries of shipbuilding, were driven nearly to extinction in the twentieth century by the introduction of a parasite. Bermuda petrels and cedars are now rare, as are other species endemic to Bermuda.

Invasive species

An "invasive species" is defined as a species that is

1. non-native (or alien) to the ecosystem under consideration,
2. occurring beyond its accepted normal distribution, and
3. threatening valued environmental, agricultural or other social resources by the damage it causes.

Invasive species can be plants, animals, and other organisms (e.g., microbes). Human actions are the primary means of invasive species introductions.

The Invasive Species Problem

Increasingly, global trade and communication are directly contributing to the mixing of faunas and floras across biogeographical boundaries. To describe this new epoch of widespread anthropogenic influence, some researchers have suggested the term ***Homogocene***.

Invasive species are either accidentally introduced or they are introduced by man to fulfill his needs. After introduction, they can expand their population and create mono-specific thickets. In this way these species can affect ecosystem processes, biodiversity patterns and community structure. Some important invasive species across the world are *Salvinia molesta*, *Eucalyptus* species, *Hakea* species, *Lantana camara*, *Caesalpinia decapetala*, *Chromolaena odoratum*,

Eichhornia crassipes and *Solanum mauritianum* in Africa; *Chrysanthemoides monilifera,S. mauritianum, Brassica tournefortii, Asparagus densiflorus, L. camara, Ardisia elliptica* and *Berberis thunbergii* in Australia; *Fallopia japonica, Impatiens glandulifera, Rhododendron ponticum, Gleditsia triacanthos Crassula helmsii, Acer pseudoplatanus* and *Ailanthus altissima* in Europe; *Centaurea diffuas, Bromustectorum, Hydrilla verticillata, Melaleucaquinquenervia, Mimosa pudica, Tamarix spp., Panicum repens, E. crassipes, Centaurea solstitialis, Phragmites australis* and *Imperata cylindrica* in North Americancontinent.

Species suddenly taken to new environments may fail to survive but often they thrive, and they become invasive. This process, together with habitat destruction, has been a major cause of extinction of native species throughout the world in the past few hundred years. Although in the past many of these losses have gone unrecorded, today, there is an increasing realisation of the ecological costs of biological invasion in terms of irretrievable loss of native biodiversity.

Factors conferring invasiveness

Factors, which play a key role in the successful establishment and survival of these species, are:

1. unrestrained vegetative spread
2. escape from biotic constraints
3. prolific seed production
4. highly successful seed dispersal, germination, and colonization
5. adaptive morphological and ecological characters
6. superior propagule characteristics favoring greater mobility, and
7. ability to supplant native flora either competing for resources or exerting allelopathic effects.

Invasion Process

There are three major phases of plant invasion: i*ntroduction, colonization* and *naturalization*. When an ecosystem is disturbed either by natural processes or due to some anthropogenic factors, it provides a kind of invasion window to the alien propagule. Gradually, it overcomes the environmental, reproductive and dispersal barriers and expands its population. Environmental factors like resources availability favoring establishment of alien propagule are believed to be the most important at introduction phase because introduced propagule has to compete with the established flora that is already well adapted to the site. Figure 1 provides an insight into the invasion process and also in the control strategies.

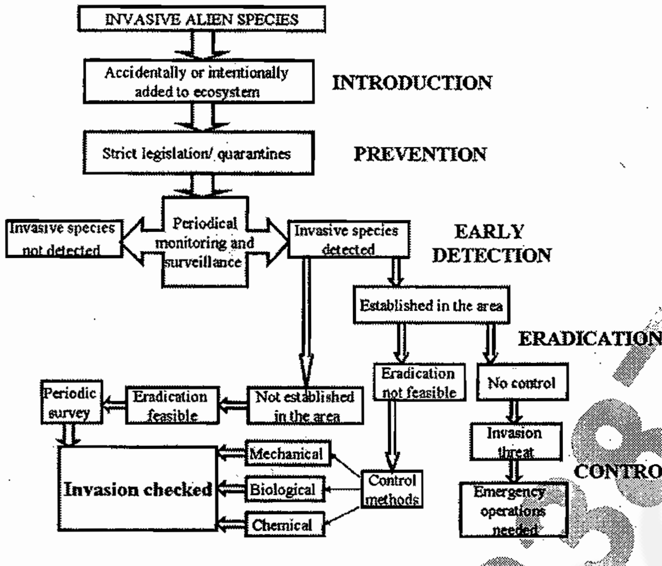


Figure 1: Invasion process and the control strategies

Some important invasive species in India

Some invasive species found in Indian subcontinent, their country of origin, habitats invaded and impact on ecosystems are presented in the table below.

Invading species	Country of Origin	Habitats invaded	Impact on ecosystem
1. *Ageratum conyzoides*	Central and South America	In wastelands and outskirts	Fast growth and easily dispersable seeds help in fast spreading and it also has allelopathic inhibition against native species.
2. *Eichhornia crassipes*	Brazil	Ponds and water bodies having blockages	Hinders navigation, chokes water bodies and reduces biodiversity by causing anoxia and degrades water quality.
3. *Eypatorium odoratum*	Mexico	Forest roads	Capable of growing much faster than native species and is a problem in plantation areas.
4. *Eupatorium adenophorum*	America, mainly Mexico	Warm and humid areas having early successional communities developed after slash and burn agriculture	Reproductive capacity and ecological adaptive capacity are strong and it grows very fast and causes allelopathic inhibition
5. *Ipomoea carnea*	Tropical America	Wetland having large amount of sand and clay	Due to fast growth rate, it is replacing native species and have negative effects on wetlands because of semi-aquatic nature.
6. *Lantana camara*	Tropical and subtropical America	Wastelands and disturbed forests areas	High nutrient extraction efficiency favors its faster growth than natives and supplant native vegetation.
7. *Mikania micrantha*	Tropical America	In jhum cultivated areas	Prevents forest regeneration in invaded areas.

8. *Prosopis juliflora*	West Indies and tropical America	In open dry places	It forms almost pure populations wherever it invades and excludes all native species due to its allelopathic effects.
9. *Parthenium hysterophorus*	West Indies, central and south America	Open wastelands and cultivated fields	Its prolific seed production and fast spreading capability favors its growth; it also has strong allelopathic effect.
10. *Salvinia molesta*	Southeastern Brazil	Best in stagnant or slow-flowing water	Suppresses growth of native species in water bodies, forms floating mats.

Impact of invasion

Invasion is considered as the second most important threat to biodiversity after habitat destruction.

Invasive species modify all the major ecosystem processes in the way, which suits them best. Alteration in litter dynamicsis the first and foremost impact observed in the ecosystem, which an invader invades. Gradually other ecosystem processes depending on litter dynamics *viz.* soil biota,nutrient dynamics and biogeochemical cyclesare also modified. Later, geomorphology and hydrology of the areaare also changed as invasion proceeds. During the course of establishment, these invasive species also interfere with native species recruitmenteither by allelopathic suppressionor by competing with seedlings for resources.

The invasive species are also known to alter fire regimes.

Management of invaders

Invasive species cause degradation of ecosystem. As an invasive species is established in an ecosystem it interferes with the growth and recruitment of other native species. Further, once equilibrium among species has occurred, it further disturbs homeostasis of ecosystem and weakens it. Accidental introduction is not easily checked but intentional introduction of alien species should be done with prior assessment so that they may not harm the ecological integrity of an ecosystem. For management of these species basic strategy of prevention, eradication and control should be adopted as explained in Figure 1. While opting for biological control methods we should take care that the biological agents may not create a problem in later years.

Concluding remarks

Invasion is considered as the second most important threat to biodiversity after habitat destruction. IUCN defines alien invasive species, as a species that becomes established in natural or semi-natural ecosystem or habitat, is an agent of change and threatens biological diversity. Invasive species are so much important in the present scenario that, article 8(h) of the Biodiversity Convention asks for measures "to prevent the introduction, control or even eradication of those alien species which threaten ecosystems, habitats or species".

Chapter 14: Environment (Protection) Act; Environmental Impact Assessment

Environment (Protection) Act

Background

The Environment (Protection) Act, 1986 was enacted by the Parliament in the year 1986 in the wake of the Bhopal Gas Tragedy which took place in the year 1984. The Act was made under Article 253 of the Constitution to implement the decisions of the United Nations Conference on the Human Environment of 1972. India which was one of the parties to the conference undertook an obligation to implement all possible measures in relation to the protection and improvement of the human environment and the prevention of hazards to human beings, other living creatures, plants and property.

An overview of the Act

The **Environment (Protection) Act, 1986** (EPA) was passed to protect and improve human environment and to prevent hazards to human beings, other than plants and property.

The purpose of the Act is to implement the decisions of the United Nations Conference on Human Environment of 1972.

The scope of the EPA is broad, with "environment" defined to include water, air, land and the inter relationships which exists among water, air and land and human beings and other living creatures, plants, micro-organisms and property. The law also promulgates rules on hazardous waste management and handling.

The Act also defines the responsibilities of handlers, circumstances for granting authorization, conditions of disposal sites, rules for importing hazardous wastes, reporting of accidents, packaging and labeling requirements and an appeal process for potential handlers who have been denied authorization.

Rules were also promulgated on the manufacture, storage and import of hazardous or toxic chemicals, microorganisms, genetically engineered organisms, or cells.

The EPA is an umbrella legislation designed to provide a framework for Central Government coordination of the activities of various Central and State authorities established under previous laws, such as Water Act and Air Act. Since the Act entered the statute book, it has served to back a vast body of subordinate environmental legislations in India.

The provisions of the Act

The Act is very small one framed with 4 chapters containing a total 26 sections. Chapter 1 deals preliminary aspects like scope of the Act, definitions of certain important terms. Chapter 2 contains the provisions which given general power to the Central Government to take all measures to improve the quality of environment. Chapter 3 lays out the substantive provisions relating to prevention, control and abatement of environmental pollution and also contains the penal provisions. The last chapter deals with miscellaneous aspects.

Section 3 to 6 of the Act lays down the general powers of the Central Government relating to the protection of the environment. Section 3 of the Act contains provisions as to the powers of Central

Government to take measures to protect and improve environment. The Act confers sweeping powers in the hands of Central Government to take all such measures as it deems necessary or expedient for the purpose of protecting and improving the quality of the environment and preventing, controlling and abating environmental pollution.

The Environment Act confers on the Central Government the power to restrict areas where certain industries, processes and operations shall not be carried out or shall be carried out subject to certain safeguards.

The Environment Act confers in the Central Government the power to establish and recognise environment laboratories and to appoint and recognize Government analysts.

By virtue of this power the Central Governement has passed various rules on the matter relating to environment, biodiversity, noise, hazardous substances etc. Eg : The Municipal Solid Waste (Management and Handling) Rules, 2000 etc. Other powers of the Central Government include powers to enter any place under Section 10 of the Act.

Environmental Impact Assessment (EIA)

Introduction

Environmental Impact Assessment (EIA) is an important management tool for ensuring optimal use of natural resources for sustainable development. A beginning in this direction was made in our country with the impact assessment of river valley projects in 1978-79 and the scope has subsequently been enhanced to cover other developmental sectors such as industries, thermal power projects, mining schemes etc.

EIA has now been made mandatory under the Environmental (Protection Act, 1986 for 29 categories of developmental activities involving investments of Rs. 50 crores and above.

Environmental Appraisal Committees

With a view to ensure multi-disciplinary input required for environmental appraisal of development projects, Expert Committees have been constituted for the following sectors:

1. Mining Projects
2. Industrial Projects
3. Thermal Power Projects
4. River Valley, Multipurpose, Irrigation and H.E. Projects
5. Infrastructure Development and Miscellaneous Projects
6. Nuclear Power Projects
7. Environmental Appraisal Procedure

Once an application has been submitted by a project authority along with all the requisite documents specified in the EIA Notification, it is scrutinised by the technical staff of the Ministry prior to placing it before the Environmental Appraisal Committees.

The Appraisal Committees evaluate the impact of the project based on the data furnished by the project authorities and if necessary, site visits or on-the-spot assessment of various

environmental aspects are also undertaken. Based on such examination, the Committees make recommendations for approval or rejection of the project, which are then processed in the Ministry for approval or rejection.

The EIA process

The steps followed in EIA are broadly as follows.

1. **Scoping** – It is a process of detailing terms of reference of EIA. It determines the significant impacts to be considered in EIA
2. **Baseline Data** – It describes the existing environmental status of the identified study area. The site-specific primary data should be monitored for the identified parameters and supplemented with secondary data.
3. **Impact Prediction** – It is a way of mapping the environmental consequences of the significant aspects of the project and its alternatives. The following aspects are studied:
    - *Air Quality* – changes in ambient levels and ground level concentrations due to total emissions etc
    - Water Quality – Availability to competing users, changes in water quality, ingress of saline etc
    - *Noise* – Changes in ambient level, effect on fauna and human health
    - Deforestation and animal habitat shrinkage
    - *Socio economic impacts* like demographic changes, availability of employment etc
4. **Assessment of alternatives, Mitigation Measures and EIA Report** – For every project possible alternatives should be identified and environmental attributes compared. Alternatives should cover NO PROJECT option also. An EIA Report provides clear information to the decision maker on the different environmental scenarios without the project, with the project and with project alternatives.
5. **Public Hearing** – After the completion of the report the law requires that public must be informed and consulted on proposed development. Generally the State Pollution Control Boards conduct the public hearing. The people who are affected have the right to give oral or written suggestions.
6. **Decision Making** – Decision making process involve consultation between the project proponent, and the impact assessment authority.

In case of site specific projects such as Mining, River Valley, Ports and Harbours etc., a two stage clearance procedure has been adopted whereby the project authorities have to obtain site clearance before applying for environmental clearance of their projects. This is to ensure avoiding areas which are ecologically fragile and environmentally sensitive. In case of projects where complete information has been submitted by the project proponents, a decision is taken within 90 days.

Monitoring

After considering all the facets of a project, environmental clearance is accorded subject to implementation of the stipulated environmental safeguards. Monitoring of cleared projects is undertaken by the six regional offices of the Ministry functioning at Shillong, Bhubaneshwar, Chandigarh, Bangalore, Lucknow and Bhopal. The primary objective of such a procedure is to ensure adequacy of the suggested safeguards and also to undertake mid-course corrections required, if any. The procedure adopted for monitoring is as follows:

Project authorities are required to report every six months on the progress of implementation of the conditions/safeguards stipulated, while according clearance to the project.

Field visits of officers and expert teams from the Ministry and/ or its Regional Offices are undertaken to collect and analyse performance data of development projects, so that difficulties encountered are discussed with the proponents with a view to finding solutions.

In case of substantial deviations and poor or no response, the matter is taken up with the concerned State Government.

Changes in scope of project are identified to check whether review of earlier decision is called for or not.

Some recent developments

1. **In October 2012**, the Union Minister for Environment and Forests stated that the Government plans to add biodiversity conservation as a new criterion to grant environmental and forest clearances. There is no biodiversity clearance till now. The Biodiversity Act says the Government must assess the impact of any industrial or developmental activity on biodiversity. However, this has so far been largely ignored. Environmental impact assessment reports usually include a list of flora and fauna in the affected area, but there is little understanding of the interaction between species or the wider impact on biodiversity in the area.

2. **In June 2016**, the Ministry of Environment, Forest and Climate Change (MoEF) has issued a draft notification seeking to amend the Environmental Impact Assessment (EIA) of 2006, allowing those who violate this law to continue work with an Environment Supplement Plan (ESP).

Conclusion

In the view of the fact that development is an ever growing process and its impact on the environment is also ever increasing, leading to rapid deterioration in environmental conditions, the critical importance of EIA lies in the fact that it provides a rational approach to sustainable development.

Chapter 15: Plant Indicators and Phytoremediation

Plant Indicators

Organisms, chiefly plants, species, communities or even systems serve as a measure or index (indicator) of the environment. If plants serve as indicators, they are called plantindicators.

By definition, an **indicator species** is any biological species that defines a trait or characteristic of the environment. For example, a species may delineate an eco-region or indicate an environmental condition such as a disease outbreak, pollution, species competition or climate change. Indicator species can be among the most sensitive species in a region, acting as an early warning to monitoring biologists.

An **indicator plant** is usually a wildly growing plant that grows in some specific environment, allowing an assessment of soil and other conditions in a place by simple observation of vegetation.

Underlying principles

1. Every plant is a product of the conditions under which it grows and is therefore, a measurement of environment, conditions, resources, processes and uses.
2. Dominant species in an area are most important indicators, as they receive the full impact of the habitat for over longer periods. Consequently, plant communities are more reliable indicators than individual plants.
3. Numerical relationship between species, populations and whole communities are more reliable than single species.
4. Large species serve as better indicators than small species; usually **'steno'** species serve much better indicators than **'eury'** species.

Examples of indicator plant categories

Some of the obvious cases where plants and to some extent animals also, serve as indicators of some characteristic types of environmental conditions are as follows:

Indicators of Potential Productivity of Land

Forests serve as good indicators of land productivity. For example, vegetative growth of trees like species of *Quercus (Q. marilandica, Q.stellata)* is comparatively poor on lowland or sterile sandy soil than the normal soil in which they grow under natural conditions.

Indicators of Agriculture

Native vegetation of a particular region is the safe criterion of agricultural possibilities. Thus, plants growing under natural conditions provide information on capabilities of land for crop growth than those obtained through meteorological data or soil analysis.

For example:

1. Fertile soil supports plants such as nettles, chickweed, groundsel and fat hen.

2. Nitrogen-deficient conditions are indicated by the presence of nitrogen fixing legumes such as clovers or vetches.

Indicators of Climate

Plant communities characteristic of a particular region provide information on the climate of that area. For instance, evergreen forests indicate high rainfall in winter as well as summer; sclerphyllous vegetation indicate heavy rainfall in winter and low during summer; grasslands indicate heavy rains during summer and low during winter; xerophytic vegetation indicate' a very low or no rainfall in the year.

Indicators of Soil Type and Other Soil Characteristics

Luxuriant growth of some taller and deeply rooted grasses like *Psoralea* indicates a sandy loam type of soil, whereas the presence of grasses *Andropogon* indicates sandy soil. *Rumex acetosella* indicates an acid grassland soil, whereas *Spermacoce stricta* the iron-rich soil in the area. Plants like *Chrozophora rottleri, Heliotropium supinum* and *Polygonum plebejum* grow better in low-lying lands. *Shorea robusta, Cassia obtusifolia, Geranium* sp. and *Impatiens* sp. indicate proper aeration of soil. Grasses like *Saccharum spontaneum* prefer to grow in poorly-drained soils. Plants *as Artemisia tridentata, Kochia vesrita, Salicomia utahensis* and S. *rubra* indicate saline soils. *Capparis spinosa* and *Carissa spinaum* indicate intense soil erosion.

Indicators of Fires

Some plants as *Agrostis hiemalis, Epilobium spicatum, Pinum contorta, Populus termuloides, Pteris aquilina* and *Pyronema confluens* (fungus) dominate in areas destructed by fires. *Pteridium* spp. in particular indicates burnt and highly disturbed coniferous forests.

Indicators of Pollution

Plants like *Utricularia, Chara, Wolffia* prefer to grow in polluted waters. Bacteria, like *Escherichia coli* also indicate water pollution. Presence of diatoms in water indicates pollution by sewage. Movement of fish like *Catla catla, Labeogoniu, L. bata, L. rohita* and *Natopterus natopterus* away from the water indicates industrial pollution of water.

Indicators of Overgrazing

Annual weeds and short-lived perennials like *Amaranthus, Chenopodium* and *Polygonum* etc. grow better in overgrazed areas. Frequent visits of the areas by animals as cattle, horses, sheeps, goats etc. also indicate that the area is under intense grazing.

Advantages of plant indicators

1. Plant based methods of monitoring may provide information about the state of environment due to their following characteristic features at different levels:

2. Plants have the ability to accumulate a hazardous substance occurring in the environment. They may thus indicate the presence of such a substance

3. Life processes of different organisms can be used to evaluate the action of environmental pollution and that of a given pollutant

4. Changes in the pollution of species and in the structure of ecosystem can indicate the level of environmental deterioration.

5. Biological systems as indicators of the environment, therefore, have a remarkable potential in forecasting of disasters as well as prevention of pollution.

Phytoremediation

Introduction to phytoremediation

Phytoremediationdescribes the treatment of environmental problems (bioremediation) through the use of plants. Phytoremediation is a process that uses plants to remove, transfer, stabilize, or destroy contaminants in soil, sediment, and groundwater.

Phytoremediation consists in depolluting contaminated soils, water or air with plants able to contain, degrade or eliminate metals, pesticides, solvents, explosives, crude oil and its derivatives, and various other contaminants, from the mediums that contain them. It is clean, efficient, inexpensive and non-environmentally disruptive, as opposed to processes that require excavation of soil.

Phytoremediation may be applied in situ or ex situ, to soils, sludges, sediments, other solids, or groundwater.

Phytoremediation applies to all biological, chemical, and physical processes that are influenced by plants (including the rhizosphere) and that aid in cleanup of the contaminated substances. Plants can be used in site remediation, both through the mineralization of toxic organic compounds and through the accumulation and concentration of heavy metals and other inorganic compounds from soil into aboveground shoots. The mechanisms of phytoremediation include:

1. **Enhanced rhizosphere biodegradation** (takes place in soil or groundwater immediately surrounding plant roots),

2. **Phytoextraction** (also known as phytoaccumulation, the uptake of contaminants by plant roots and the translocation/accumulation of contaminants into plant shoots and leaves),

3. **Phytotransformation** - chemical modification of environmental substances as a direct result of plant metabolism, often resulting in their inactivation, degradation (phytodegradation)

4. **Phytostabilization**- production of chemical compounds by plants to immobilize contaminants at the interface of roots and soil.

5. **Phytostimulation** - enhancement of soil microbial activity for the degradation of contaminants, typically by organisms that associate with roots. This process is also known as *rhizosphere degradation.*

6. **Phytovolatilization** - removal of substances from soil or water with release into the air, sometimes as a result of phytotransformation to more volatile and / or less polluting substances.

7. **Rhizofiltration** - filtering water through a mass of roots to remove toxic substances or excess nutrients. The pollutants remain absorbed in or adsorbed to the roots.

The principal approaches of phytoremediation

Phytoextraction

Phytoextraction (or *phytoaccumulation*) uses plants to remove contaminants from soils, sediments or water into harvestable plant biomass. Phytoextraction has been growing rapidly in popularity world-wide for the last twenty years or so. Generally, this process has been tried more often for extracting heavy metals than for organics. At the time of disposal, contaminants are typically concentrated in the much smaller volume of the plant matter than in the initially contaminated soil or sediment. 'Mining with plants', or **phytomining**, is also being experimented with.

The plants absorb contaminants through the root system and store them in the root biomass and/or transport them up into the stems and/or leaves. A living plant may continue to absorb contaminants until it is harvested. After harvest, a lower level of the contaminant will remain in the soil, so the growth/harvest cycle must usually be repeated through several crops to achieve a significant cleanup. After the process, the cleaned soil can support other vegetation.

Two versions of phytoextraction:

- **natural hyper-accumulation**, where plants naturally take up the contaminants in soil unassisted, and
- **induced or assisted hyper-accumulation**, in which a conditioning fluid containing a chelator or another agent is added to soil to increase metal solubility or mobilization so that the plants can absorb them more easily. In many cases natural hyperaccumulators are metallophyte plants that can tolerate and incorporate high levels of toxic metals.

Examples of phytoextraction from soils

Arsenic, using the Sunflower (*Helianthus annuus*), or the Chinese Brake fern (*Pteris* spp), a hyperaccumulator. Chinese Brake fern stores arsenic in its leaves.

- Cadmium and zinc, using alpine pennycress (*Thlaspi caerulescens*), a hyperaccumulator of these metals at levels that would be toxic to many plants. On the other hand, the presence of copper seems to impair its growth.
- Lead, using Indian Mustard (*Brassica juncea*), Ragweed (*Ambrosia artemisiifolia*), Hemp Dogbane (*Apocynum cannabinum*), or Poplar trees, which sequester lead in its biomass.
- Salt-tolerant (moderately halophytic) barley and/or sugar beets are commonly used for the extraction of Sodium chloride (common salt) to reclaim fields that were previously flooded by sea water.
- Uranium, using sunflowers, as used after the Chernobyl accident.
- Mercury, selenium and organic pollutants such as polychlorinated biphenyls (PCBs) have been removed from soils by transgenic plants containing genes for bacterial enzymes

Phytostabilization

Phytostabilization focuses on long-term stabilization and containment of the pollutant. For example, the plant's presence can reduce wind erosion, or the plant's roots can prevent water

erosion, immobilize the pollutants by adsorption or accumulation, and provide a zone around the roots where the pollutant can precipitate and stabilize. Unlike phytoextraction, phytostabilization mainly focuses on sequestering pollutants in soil near the roots but not in plant tissues. Pollutants become less bioavailable and livestock, wildlife, and human exposure is reduced. An example application of this sort is using a vegetative cap to stabilize and contain mine tailings.

Phytotransformation

In the case of organic pollutants, such as pesticides, explosives, solvents, industrial chemicals, and other xenobiotic substances, certain plants, such as Cannas, render these substances non-toxic by their metabolism. In other cases, microorganisms living in association with plant roots may metabolize these substances in soil or water. These complex and recalcitrant compounds cannot be broken down to basic molecules (water, carbondioxide etc) by plant molecules, and hence the term phytotransformation represents a change in chemical structure without complete breakdown of the compound.

The term "**Green Liver Model**" is used to describe phytotransformation, as plants behave similar to the human liver when dealing with these xenobiotic compounds(foreign compound/pollutant). After uptake of the xenobiotics, plant enzymes increase the polarity of the xenobiotics by adding functional groups such as hydroxyl groups (-OH). This is known as Phase I metabolism, similar to the way the human liver increases the polarity of drugs and foreign compounds.While in the human liver, enzymes like Cytochrome P450s are responsible for the initial reactions, in plants enzymes such as nitroreductases carry out the same role. In the second stage of phytotransformation, known as Phase II metabolism, plant biomolecules such as glucose and amino acids are added to the polarized xenobiotic to further increase the polarity (known as conjugation). This is again similar to the processes occurring in the human liver wherein glucuronidation (addition of glucose molecules by the UGT (e.g. UGT1A1) class of enzymes) and glutathione addition reactions occur on reactive centers of the xenobiotic. Phase I and II reactions serve to increase the polarity and reduce the toxicity of the compounds, although many exceptions to the rule are seen at least in the case of the human liver. The increased polarity also allows for easy transport of the xenobiotic along aqueous channels. In the final stage of phytotransformation (Phase III metabolism), a sequestration of the xenobiotic occurs within the plant. The xenobiotics polymerize in a lignin-like manner and get a complex structure which is sequestered in the plant. This ensures that the xenobiotic is safely stored in the plant, and does not affect the functioning of the plant. However, preliminary studies have shown that these plants can be toxic to small animals (such as snails) and hence plants involved in phytotransformation may need to be maintained in a closed enclosure. The human liver differs from plants in Phase III metabolism, since the liver can transport the xenobiotics into the bile for eventual excretion. Since plants have no excretory mechanisms, they sequester the modified xenobiotics. Hence, the plants reduce toxicity (with exceptions) and sequester the xenobiotics in phytotransformation. Trinitrotoluene phytotransformation has been extensively researched a transformation pathway has been proposed .

Advantages and limitations of phytoremediation

Advantages

1. The cost of the phytoremediation is lower than that of traditional processes both *in situ* and *ex situ*
2. The plants can be easily monitored

3. The possibility of the recovery and re-use of valuable metals (by companies specializing in "phytomining")
4. It is the least harmful method because it uses naturally occurring organisms and preserves the natural state of the environment.

Limitations

1. Phytoremediation is limited to the surface area and depth occupied by the roots.
2. Slow growth and low biomass require a long-term commitment
3. With plant-based systems of remediation, it is not possible to completely to prevent the leaching of contaminants into the groundwater (without the complete removal of the contaminated ground which in itself does not resolve the problem of contamination)
4. The survival of the plants is affected by the toxicity of the contaminated land and the general condition of the soil.
5. Possible bio-accumulation of contaminants which then pass into the food chain, from primary level consumers upwards.

Chapter 16: Intellectual Property Rights and Farmers' Rights

Intellectual Property Rights (IPR)

The concept of IPR

Intellectual property (IP) refers to creations of the mind: inventions, literary and artistic works, and symbols, names, images, and designs used in commerce.

IP is divided into two categories:

1. **Industrial property**, which includes inventions (patents), trademarks, industrial designs, and geographic indications of source; and
2. **Copyright**, which includes literary and artistic works such as novels, poems and plays, films, musical works, artistic works such as drawings, paintings, photographs and sculptures, and architectural designs. Rights related to copyright include those of performing artists in their performances, producers of phonograms in their recordings, and those of broadcasters in their radio and television programs.

The innovations and creative expressions of indigenous and local communities are also IP, yet because they are "traditional" they may not be fully protected by existing IP systems.

The Convention Establishing the World Intellectual Property Organization (WIPO), concluded in Stockholm on July 14, 1967 (Article 2(viii)) provides that "intellectual property shall include rights relating to:

1. literary, artistic and scientific works,
2. performances of performing artists, phonograms and broadcasts,
3. inventions in all fields of human endeavor,
4. scientific discoveries,
5. industrial designs,
6. trademarks, service marks and commercial names and designations,
7. protection against unfair competition,
8. all other rights resulting from intellectual activity in the industrial, scientific, literary or artistic fields.

World Intellectual Property Organization (WIPO)

The World Intellectual Property Organization is the United Nations agency dedicated to the use of intellectual property (patents, copyright, trademarks, designs, etc.) as a means of stimulating innovation and creativity.

It was created in 1967. It is headquartered in Geneva, Switzerland. The current Director-General of WIPO is Francis Gurry, who took office on October 1, 2008

The terms governing WIPO's mandate, functions, finances and procedures are set out in the WIPO Convention. All decisions governing WIPO's strategic direction and activities are made by the member states. The WIPO Secretariat coordinates formal and informal meetings of the member state bodies throughout the year.

TRIPs

Introduction

TRIPS is the most important and comprehensive international agreement on intellectual property rights which came into effect on 1 January 1995. The Agreement on Trade Related Intellectual Property Rights was negotiated with other international trade agreements during the Uruguay Round trade negotiations of the GATT (General Agreement on Tariffs and Trade) from 1986 to 1994. As one of the World Trade Organization (WTO) agreements, it is totally binding for all WTO Member States.

The Agreement covers most forms of intellectual property including patents, copyright and related rights (i.e. the rights of performers, producers of sound recordings and broadcasting organizations), industrial designs; patents including the protection of new varieties of plants; the layout-designs of integrated circuits, trademarks, geographical indications, industrial designs, trade secrets, and exclusionary rights over new plant varieties.

The three main features of the Agreement are:

Standards

In respect of each of the main areas of intellectual property covered by the TRIPS Agreement, the Agreement sets out the minimum standards of protection to be provided by each Member. Each of the main elements of protection is defined, namely the subject-matter to be protected, the rights to be conferred and permissible exceptions to those rights, and the minimum duration of protection.

The Agreement sets these standards by requiring, first, that the substantive obligations of the main conventions of the WIPO, the Paris Convention for the Protection of Industrial Property (Paris Convention) and the Berne Convention for the Protection of Literary and Artistic Works (Berne Convention) in their most recent versions must be complied with. The TRIPS Agreement is thus sometimes referred to as a Berne and Paris-plus agreement.

Enforcement

The second main set of provisions deals with domestic procedures and remedies for the enforcement of intellectual property rights. The Agreement lays down certain general principles applicable to all IPR enforcement procedures. In addition, it contains provisions on civil and administrative procedures and remedies, provisional measures, special requirements related to border measures and criminal procedures, which specify, in a certain amount of detail, the procedures and remedies that must be available so that right holders can effectively enforce their rights.

Dispute settlement

The Agreement makes disputes between WTO members about the respect of the TRIPS obligations subject to the WTO's dispute settlement procedures.

The obligations under the Agreement will apply equally to all member countries, but developing countries have a longer period to phase them in.

The TRIPS Agreement is a minimum standards agreement, which allows members to provide more extensive protection of intellectual property if they so wish. Members are left free to determine the appropriate method of implementing the provisions of the Agreement within their own legal system and practice.

Substantive standards of protection under TRIPs

Copyright

It gives the creators of a wide range of material, such as literature, art, music, sound recordings, films and broadcasts, economic rights enabling them to control use of their material in a number of ways, such as by making copies, issuing copies to the public, performing in public, broadcasting and use on-line. It also gives moral rights to be identified as the creator of certain kinds of material, and to object to distortion or mutilation of it. The purpose of copyright is to allow creators to gain economic rewards for their efforts and so encourage future creativity and the development of new material which benefits us all. However, copyright protection extends to expressions and not to ideas, procedures, methods of operation or mathematical concepts as such.

Computer programs, whether in source or object code, are protected as literary works. Databases are eligible for copyright protection provided that they by reason of the selection or arrangement of their contents constitute intellectual creations.

Related rights

The provisions on protection of performer, producers of phonograms and broadcasting organizations constitute the related rights. Performers shall have the possibility of preventing the unauthorized fixation of their performance on a phonogram (e.g. the recording of a live musical performance). The fixation right covers only aural, not audiovisual fixations. Broadcasting organizations have the right to prohibit the unauthorized fixation, the reproduction of fixations, and the rebroadcasting by wireless means of broadcasts, as well as the communication to the public of their television broadcasts. The term of protection is at least 50 years for performers and producers of phonograms, and 20 years for broadcasting organizations.

Trademarks

A trademark is a distinctive sign which identifies certain goods or services as those produced or provided by a specific person or enterprise. The system helps consumers identify and purchase a product or service because its nature and quality, indicated by its unique trademark, meets their needs. Trademark provides protection to the owner of the mark by ensuring the exclusive right to use it, to identify goods or services, or to authorize another to use it in return for payment. The period of protection varies, but a trademark can be renewed indefinitely beyond the time limit on payment of additional fees. Trademark protection is enforced by the courts, which in most systems have the authority to block trademark infringement. Trademarks may be one or a combination of words, letters, and numerals. They may consist of drawings, symbols, three-dimensional signs such as the shape and packaging of goods, audible signs such as music or vocal sounds, fragrances, or colors used as distinguishing features.

Patent

Patent protects new inventions and covers how things work, what they do, how they do it, what they are made of and how they are made. If a patent application is granted, it gives the owner the ability to take a legal action under civil law to try to stop others from making, using, importing or selling the invention without permission. This may involve suing the alleged infringer through the courts. The TRIPS Agreement requires member countries to make patents available for any inventions, whether products or processes, in all fields of technology without discrimination, subject to the normal tests of novelty, inventiveness and industrial applicability.

There are three permissible exceptions to the basic rule on patentability:

One is for inventions contrary to ordre public or morality-this explicitly includes inventions dangerous to human, animal or plant life or health or seriously prejudicial to the environment.

The second exception is that members may exclude from patentability diagnostic, therapeutic and surgical methods for the treatment of humans or animals.

The third is that members may exclude plants and animals other than micro-organisms and essentially biological processes for the production of plants or animals other than non-biological and microbiological processes. Any country excluding plant varieties from patent protection must provide an effective sui generis system of protection. (Article 27.3 (b).

Geographical Indication

A geographical indication is a sign used on goods that have a specific geographical origin and possess qualities, reputation or characteristics that are essentially attributable to that place of origin. Most commonly, a geographical indication includes the name of the place of origin of the goods. Agricultural products typically have qualities that derive from their place of production and are influenced by specific local factors, such as climate and soil. Whether a sign is recognized as a geographical indication is a matter of national law. Geographical indications may be used for a wide variety of products, whether natural, agricultural or manufactured.

IPRs relevant to agriculture

Several of the IPRs mentioned above are relevant to the agricultural sector in that **they can be used to protect goods or services produced in the agricultural sector.** These are mainly patents, plant breeders' rights, trademarks, geographical indications and trade secrets. It is possible to include lay-out designs for chips that are designed to perform certain functions related to agriculture, but these are assumed to be incorporated in machines produced in the industrial sector. Similarly, scientific papers or television programmes covering ideas related to agriculture are not seen as directly being produced in this sector. The relevant IPRs are dealt with below.

Patents are probably the most important IPR today for agricultural goods and services as they provide, wherever these are available, the strongest protection for patentable plants and animals and biotechnological processes for their production. Patents universally give the patentee the right to prevent third parties from making, using or selling the patented product or process. Patents, however, have to be disclosed to the public through the patent documents. This enables researchers to develop further useful products or services. Patentable products have to meet the criteria of patentability, viz., novelty, i.e. that which is not known in the prior art, non-obviousness i.e. that which involves an inventive step and usefulness i.e. that which is industrially applicable. With some nuanced differences the patent laws of all countries follow

these criteria. However, not all countries allow the patenting of plants and animals or even microorganisms or biotechnological processes.

Biotechnology is the sector that holds the most potential for advances in agriculture to improve productivity. Biotechnology R&D is mostly concentrated in the hands of large multinational enterprises in the US, Europe and Japan. It is in this field of technology more than others, that proprietary rights over knowledge is getting increasingly important. Today, in the United States, patents are even granted to animal inventions and human gene sequences, if these are eligible for such protection. The case law in the United States developed rapidly since the early '80's with the grant of a patent for a bacteria that 'ate' oil spills. This gave rise to the patenting of micro-organisms found in nature, if it involved a new, inventive and useful technical intervention by man. Another landmark case was the patent granted to the 'Harvard oncomouse', useful in research on cancer. The European Union has been slower to follow suit on the patenting of plants and animals due to the opposition it faced from environmental activists in the European Parliament. This has now been largely overcome with the imminent finalization of the new Biotechnology Directive by the European Parliament, authorizing the grant of patents to plants and animals, with limited exceptions. Thus, research on the cloning of animals, which is advancing rapidly, would be eligible for patents in at least some developed countries.

Many countries have developed plant breeders' rights to reward conventional plant breeding efforts. Such sui generis protection is weaker than patent protection in that the right holders can only prevent third parties from commercially exploiting the protected material. The criteria used to grant such protection is also lower than that used to determine patentability as these are distinctness, i.e. distinguishable from earlier known varieties, uniformity i.e. display of the same essential characteristics in every plant and stability i.e. the retention of the essential characteristics on reproduction. Such protection encourages breeding efforts in the private sector. Historically, in developing countries, such efforts have emanated from the public sector or from international research institutions. It is only in recent years that developing countries have begun to institute such protection.

Marks used in commerce can be applied to both agricultural and industrial products and services. For instance, trademarks are used to market seeds or spraying services. The essential purpose of a trademark is to distinguish the goods and services of one enterprise from another, thus preventing deception of the consumer. Such protection prevents the wrongful use of commercial marks and is not limited in time, although registration may have to be renewed from time to time. Almost all countries in the world protect trademarks.

One category of commercial marks more often used in agriculture than industry are geographical indications, including appellations of origin. These are marks associated with products originating from a country, region or locality where the quality, reputation or other characteristics of the product are essentially attributable to its geographical origin. Most geographical indications relate to agricultural products or those derived from them, as in the case of wines and spirits. Protection of such marks prevents third parties from passing off their products as those originating in the given region. Famous examples are 'Champagne' for sparkling wine and 'Roquefort' for cheese from areas of these names in France or 'Darjeeling' for tea from this district in India. It is not necessary for these indications to be geographical names as in the case of 'Feta' for cheese from Greece or 'Basmati' for rice from India and Pakistan as there are no places, localities or regions with these names. Plant varieties developed with traditional knowledge and associated with a particular region can also be protected as geographical indications. The advantage in such protection is that it is not time-limited, unlike

the case of plant patents or plant breeders' rights. However, needless to say, commercial benefits can be derived from the protection of geographical indications only when the name becomes reasonably famous.

Trade secret protection can be used by the agricultural sector to protect, for instance, hybrid plant varieties. Thus, even in countries that do not recognize plant breeders' rights, the use of hybrids gives a certain degree of appropriability as long as it can be kept secret. Trade secrets can be protected against third party misappropriation through laws relating to unfair competition or to restrictive trade practices or to contract law. In the United States there are separate trade secret laws at the State level. Protection of trade secrets is not limited in time but, unlike patents, the disadvantage of this type of protection is that it is lost the moment it is discovered independently by a third party4. The advantage, at least to the proprietor, is that, unlike patents, there is no obligation to disclose the inventive or creative ideas to society.

Some developed countries protect test data submitted for obtaining marketing approval of agricultural chemicals from use by third parties for a limited period of time, generally 5 or 10 years. Such protection gives exclusive marketing rights to the originators as an incentive to recover the investment made in testing such agricultural chemicals. Although developing countries also require the submission of such test data, no exclusivity is conferred on the originator for any period of time.

Patenting in Agriculture Segment

Patenting of innovations in the agriculture segment has been practiced all through the history of the patent system.

In India, the Indian Patents Act, 1970 did not provide for protection of agricultural products; however processes used could be patented even if for a very short period, of a maximum of seven years from the date of filing of the patent application or five years from the date of sealing, whichever was shorter.

According to TRIPS Agreement which came into force in India from 2005, inventions in all areas of technology including agriculture are to be protected as long as they satisfy the basic requirements for patenting.

Patents are now being filed for agro products, food processing, agrochemicals including fertilizers, and biocides. Such efforts will continue and could have an impact on research in agriculture and food technology areas.

The Indian Patents Act, 2005 stipulates mandatory disclosure of source of the traditional knowledge or bioresource used in the invention. Presumably this requirement is connected with possible future demands of obtaining prior informed consent (PIC) for their commercial use and agreement on benefit sharing (ABS). While there have been objections from US on this, several other developing countries have followed the Indian model in their national legislations.

Sui generis System of Protection for Plant Varieties

Most of the new innovations in agriculture are related to generation of new varieties of plants and seeds. According to TRIPS, these can be protected under the patent system which in general requires that they meet the standards of novelty, inventiveness (non-obviousness) and utility as in the case of all inventions. Alternatively, they can be protected under a special form of protection (sui generis) appropriately legislated. India has opted for the latter and brought in

legislation in 2001 under the Protection of Plant Varieties and Farmers Rights (PPV &FR) Act, 2001. The Act is meant to protect the germplasm of any new plant variety if the novelty, distinctiveness, uniformity and stability (NDUS) criteria are satisfied. An important feature of the Indian Act is that it allows farmers to save, sow and sell seeds even if of a protected (by third party) variety. The associated Registry started receiving applications only in 2007 and to date the system has not proved very effective in spite of the fact that a few varieties of food crops including cereals and pulse crops have been registered. The PVP registry has provisions for storing referral samples of the registered specimens. So far the PPV & FR Act has had little impact on agriculture in the country and clearly the provisions and their implementation modalities need to be revisited, reviewed and amended if necessary.

One of the most controversial issues in recent times has been the evolution and emergence of genetically modified organisms (GMOs), in the agriculture and food segments. The desirability of patenting life forms and genetic engineering based processes and products, has by itself been questioned. TRIPS makes it mandatory to provide protection of microorganisms (without defining the term), one of the essential components of biotechnology based inventions. Such processes have the potential to improve productivity of food products apart from the ability to produce more specific and better quality foods. The best known example of a patented technology and product is Monsanto's golden rice which produces beta carotene helpful in the alleviation of blindness. Apart from the health benefits that such foods provide, the technology has the potential to improve the productivity in the agricultural sector. However, in the wake of wide spread criticism about GM crops, there has been a considerable slowdown in R&D and commercialization activities in this area. This is notwithstanding the fact that the world supply of soybean, corn etc., is based on GM technology. As of now, a major problem is the high costs of such value added products and possible future hazards of use of GMOs to human and animal health and environment. There are also concerns about the labeling requirements addressed under the Cartagena biosafety protocol. There is a direct correlation between the Cartagena protocol and international trade in living modified organisms intended for development of agriculture. Under this Protocol, an exporting country dealing with living modified organisms (LMOs), e.g., genetically modified seeds for agriculture should get the importing countries' PIC before trade is effected.

Controversy surrounding Article (27.3)

One of the controversies of Article 27.3 focuses on the meaning of 'sui generis' and exactly what is considered an 'effective' form of plant variety monopoly right. The term sui generis (Latin for 'of its own gender/genus') is not defined in the agreement, but it is generally believed that it enables member countries to fashion their own protection scheme for plants. In part because of the difficulties with this provision, Article 27.3 was to be reviewed in 1999, four years after the entry into force of the agreement. The review has never been completed, and this Article remains a hot issue. To date, some 30 countries are calling for further discussion on Article 27.3, and some have proposed:

- Rewriting the Article to exclude patents for any organisms.
- Defining in detail what an effective plant variety development right system is.
- Extending exclusionary rights of some sort to traditional or indigenous knowledge.

- Making explicit linkages with obligations for the conservation and use of biodiversity, including mandatory disclosure of the source of genetic materials used in a patented invention. It remains to be seen whether any of these proposals will be adopted.

Impact of IPR in Agriculture and Farmers' Rights in India

According to the Indian Patent Act, 1970 and subsequent amendments, patents could be applied mainly for agricultural tools and machinery or the processes for the development of agricultural chemicals. However, methods in agricultural or horticulture, life forms of other microorganisms like plant varieties, strain /breeds of animals, fish or birds as well as products derived from chemical/ biochemical processes, and any process for medicinal, surgical, curative, prophylactic or other treatments of animals or plants to render them free of diseases or to increase their economic value or that of their products as such, earlier did not constitute patentable subject matter. Inventions except for method inventions relating to substances prepared or produced by chemical processes including alloys, optical glass, semiconductors and inter-metallic compounds and **substances intended for use or capable of being used as drug and food were not patentable till the beginning of 2005**.

Form 2005, inventions related to agrichemicals as products could be patented according to the Patent (Amendments) Act, 2005. Earlier, in India, there was no legislation to protect plant varieties. However, after becoming a signatory to TRIPS Agreement need for such legislation was felt since Article 27.3 (b) of the TRIPS Agreement made it mandatory to provide protection for plant varieties either by patents or by an effective *sui generis* system or by any combination thereof, the choice having been left to the signatory states.

Sui generis enables designing of one's own system of protection for plant varieties as an alternative or addition to a patent system for protecting plants. As a result of this legislation, in India IPR protection came into being for new plant varieties, in the shape of the **Protection of Plant Varieties and Farmers' Rights (PPVFR) Act in 2001**. This development created favourable legal conditions for international partnerships in biotechnology R&D.

Countries such as USA having a strong R&D base in plant genetic engineering have chosen a robust Plant Utility Patent Legislation. India is certainly not inclined to adopt patent protection regimes for its plant varieties, rather it has shown inclination to adopt a *sui generis* legislation which is non-patent, for reasons that India is predominantly agricultural and has a strong R&D base in conventional plant breeding. While Plant Utility Patents Act provides for broad patents over plant varieties, traits and genes and even the physical parts of the plants, plant breeder's rights provide IPR only over varieties.

The UPOV (Union for Protection of New Plant Varieties) provides protection to those plant breeders who produce plant varieties fulfilling the criteria of distinctiveness, uniformity and stability (DUS). However, the current version of the UPOV in 1991 had added additional criteria of 'new' to DUS thus rendering DUS as NDUS.

The Protection of Plant Varieties and Farmers' Rights Act of India

PLANT GENETIC RESOURCES (PGRs) are the foundation for the development of a food and nutritionally secure society.In addition, plants have many uses, including feed, fibre, medicine and industrial applications. PGRs were treated as the 'heritage of mankind' and were shared freely among nations, till the concerns for conservation of biological diversity were raised by the Convention on Biological Diversity (CBD), which came into force in 1993. The conservation and sustainable utilization and access to biological diversity were considered as national sovereignty

by CBD. Consequently, many issues regarding the rights of the conservers, users, breeders, farmers and intellectual property have emerged. During 2001, significant developments have taken place with respect to the realization of the rights of breeders, farmers and local communities. The Protection of Plant Varieties and Farmers' Rights Act (PPVFR) was passed by the Indian Government in 2001.

The genesis of the Indian legislation

In India, agricultural research including the development of new plant varieties has largely been the concern of the government and public sector institutions. Earlier, India did not have any legislation to protect the plant varieties as no immediate need was felt. However, after India became signatory to the Trade Related Aspects of Intellectual Property Rights Agreement (TRIPs) in 1994, such a legislation was necessitated. Article 27.3 (b) of this agreement requires the member countries to provide for protection of plant varieties either by a patent or by an effective sui generis system or by any combination thereof. Thus, the member countries had the choice to frame legislations suiting their own system and India exercised this option. The existing Indian Patent Act, 1970 excluded agriculture and horticultural methods of production from patentability. The sui generis system for protection of plant varieties was developed integrating the rights of breeders, farmers and village communities, and taking care of the concerns for equitable sharing of benefits. It offers flexibility with regard to protected genera/species, level and period of protection, when compared to other similar legislations existing or being formulated in different countries. The Act covers all categories of plants, except microorganisms.

Objectives

The objectives of the Act are as follows:

1. To provide for the establishment of an effective system for protection of plant varieties.
2. To provide for the rights of farmers and plant breeders.
3. To stimulate investment for research and development and to facilitate growth of the seed industry.
4. To ensure availability of high quality seeds and planting materials of improved varieties to farmers.

Salient features of the Act

Authority:

The Central Government establishes an authority to be known as the Protection of Plant Varieties and Farmers' Rights Authority.

Eligibility:

For a variety to be eligible for registration, it must conform to the criteria of novelty, distinctiveness, uniformity and stability (NDUS).

Payment of annual fee:

The authority may, with the prior approval of the Central Government, by notification in the Official Gazette, impose a fee to be paid annually, by every breeder of a variety, agent and licensee thereof registered under this Act determined on the basis of benefit or royalty gained by such breeder, agent or licensee, as the case may be, in respect of the variety, for the retention of their registration under this Act.

Breeders' rights:

The certificate of registration for a variety issued under this Act shall confer an exclusive right on the breeder or his successor or his agent or licensee, to produce, sell, market, distribute, import or export of the variety.

Researchers' right:

The researchers have been provided access to protected varieties for bonafide research purposes.

Farmers' rights:

The farmers' rights of the Act define the privilege of farmers and their right to protect varieties developed or conserved by them. Farmers can save, use, sow, resow, exchange, share and sell farm produce of a protected variety except sale under a commercial marketing arrangement (branded seeds).Further, the farmers have also been provided protection of innocent infringement when, at the time of infringement,a farmer is not aware of the existence of breeder rights.

A farmer who is engaged in the conservation of genetic resources of landraces and wild relatives of economic plants and their improvement through selection and preservation,shall be entitled in the prescribed manner for recognition and reward from the Gene Fund, provided the material so selected and preserved has been used as donor of genes in varieties registrable under the Act.The expected performance of a variety is to be disclosed to the farmers at the time of sale of seed/propagating material. A farmer or a group of farmers or an organization of farmers can claim compensation according to the Act, if a variety or the propagating material fails to give the expected performance under given conditions, as claimed by the breeder of the variety.

Communities' rights:

The rights of the communities provide for compensation for the contribution of communities in the evolution of new varieties in quantums to be determined by the PPVFR Authority.

Compulsory license:

The authority can grant compulsory license, in case of any complaints about the availability of the seeds of any registered variety to public at a reasonable price. The license can be granted to any person interested to take up such activities after the expiry of a period of three years from the date of issue of certificate of registration to undertake production, distribution and sale of the seed or other propagating material of the variety.

Storage of reference samples:

The storage of 'reference samples' is an important component of this Act. It requires enough and appropriate storage infrastructure. The Authority would, therefore, have to create appropriate infrastructure for providing storage facilities at selected locations in the country.

Capacity building:

Periodic training programmes should be organized for scientists and technical personnel involved in the DUS system of testing and in local languages for tribal communities and farmers on various aspects of the Act

Conclusion

The Indian PVPFR Act appears to be an effective sui generis system providing a balance between plant breeders' rights along with farmers' rights and researchers' rights. The impact of the Indian sui generis system will be felt only after its effective implementation, and later in the areas of research and development, and ultimately in the national food and nutritional security.